THE DEVELOPMENT AND EVALUATION OF A LOW-FAT HIGH-FIBRE MUFFIN USING SIMPLESSE® AS A FAT SUBSTITUTE

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This thesis is dedicated to my husband, Kobus and children

Rachèlle, Marlise, Jeanette and Kobus

with love and gratitude

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ABSTRACT

Background

The global emphasis on prevention of chronic diseases of lifestyle and known protective effects of low-fat high-fibre diets (prudent diets) motivated the development of a low-fat high-fibre baked product.

Objective

The main objective was to evaluate the effects of partial and total replacement of oil by a protein-based fat substitute (Simplesse® Dry 100) in a high-fibre muffin.

Setting

The experimental work and sensory analyses were done in the Food Science Laboratory, Potchefstroomse Universiteit vir Christelike Hoër Onderwys, Potchefstroom. Dietitians and consumers evaluated the muffins in Potchefstroom, Pretoria, Klerksdorp and Johannesburg.

Methods

The high-fibre muffins were developed and evaluated in a step-wise programme in five sub-studies, each with its own experimental design. In order to ensure that observed effects resulted from the fat substitute, the control muffins and those containing Simplesse® were also compared to muffins in which the oil was replaced by non fat milk solids. The muffins were prepared, baked and served or stored and served under controlled conditions. Sensory descriptive analyses, sensory consumer assessment, physical determinations, proximate analyses and microbial counts, were done with standardised and validated methodologies, described in detail in each chapter.

Results

- A trained analytical descriptive panel indicated that Simplesse® can successfully replace up to 100% of the oil in high-fibre muffins without significant adverse effects on the sensory characteristics.
- The results also showed that South African dietitians found the muffins highly

acceptable, did not prefer the full-fat control, revealed a positive attitude towards all the muffin variations, and declared an intent to eat them once a week.

- Similar results were obtained when consumers evaluated the muffins.
- The results further indicated that the baked muffins could be stored at room temperature or frozen and thawed without remarkable adverse effects.
- An important finding was that replacement of oil with Simplesse® actually improved the stability of the batter during refrigeration, suggesting that oil replacement may play a significant role in developing freshly baked convenience products from refrigerated batters.

Conclusions

It is generally concluded from the results of this study that the protocol used for the evaluation of a low-fat high-fibre baked product is suitable and that non-fat milk solids (NFMS) cannot replace oil in high-fibre muffins as successfully as Simplesse®.

It is further concluded that Simplesse® is a highly successful fat replacer in high-fibre muffins. The high-fibre muffins were perceived to be highly acceptable by health professionals and consumers. The analytical panel indicated only small differences between the experimental muffins and the full-fat control muffins. Differences from the control sample did not, however, necessarily imply that the muffins were unacceptable to consumers.

UITTREKSEL

Agtergrond

Die wêreldwye klem op die voorkoming van chroniese siektes van lewenstyl en die bekende beskermende effek van laevet- hoëveseldiëte, ook bekend as die omsigtige dieet, het die ontwikkeling van 'n laevet- hoëvesel- gebakte produk gemotiveer.

Doelwit

Die hoofdoelwit was om die effek van gedeeltelike en totale vervanging van olie met 'n proteïengebaseerde vetvervanger (Simplesse® Dry 100) in 'n hoëveselmuffin te evalueer.

Omgewing

Die eksperimentele werk en sintuiglike evaluering is in die Voedselwetenskaplaboratorium van die Potchefstroomse Universiteit vir Christelike Hoër Onderwys, Potchefstroom, uitgevoer. Dieetkundiges en verbruikers het die muffins in Potchefstroom, Pretoria, Klerksdorp en Johannesburg geëvalueer.

Metodes

Die hoëveselmuffins is in 'n stapsgewyse program van vyf substudies, elk met sy eie eksperimentele ontwerp, ontwikkel en geëvalueer. Ten einde te verseker dat die effekte wat waargeneem word aan die gebruik van die vetvervanger te wyte is, is die kontrolemuffins en dié met Simplesse® ook met muffins vergelyk waarin die olie met vetvrye melkpoeier vervang is. Die muffins is onder gekontroleerde toestande berei, gebak, opgeberg en bedien. Sintuiglike analise en verbruikerstoetse, fisiese bepalings, proksimale chemiese analise en mikrobiese tellings is met behulp van gestandaardiseerde en geldige metodes, soos in elke hoofstuk beskryf, uitgevoer.

Resultate

- 'n Opgeleide analitiese beskrywende proepaneel het aangedui dat Simplesse® Dry 100 tot 100% van die olie in hoëveselmuffins met sukses kan vervang sonder betekenisvolle nadelige effekte op die sintuiglike eienskappe.

- Die resultate het ook getoon dat Suid-Afrikaanse dieetkundiges (a) die muffins hoogs aanvaarbaar bevind het, (b) nie die volvetkontrole verkies het nie, (c) 'n positiewe houding teenoor al die muffinvariasies geopenbaar het en (d) van voorneme is om dit een keer per week te eet.

- Ooreenstemmende resultate is verkry wanneer verbruikers die muffins geëvalueer het.

- Die resultate het verder aangedui dat die gebakte muffins by kamertemperatuur opgeberg of gevries en daarna ontdooi kan word sonder merkbare nadelige effekte.

- 'n Belangrike bevinding was dat vervanging van olie met Simplesse® in werklikheid die stabiliteit van die beslag gedurende verkoeling verbeter het, wat daarop dui dat olievervanging moontlik 'n belangrike rol in die ontwikkeling van vars gebakte geriefsprodukte wat van koelopgebergde beslag berei is, mag speel.

Gevolgtrekkings

Die resultate van hierdie studie het tot die algemene gevolgtrekking gelei dat die protokol wat vir die evaluering van 'n laevet- hoëvesel- gebakte produk gebruik is, geskik is en dat vetvrye melkpoeier nie olie, so suksesvol as Simplesse®, in hoëveselmuffins kan vervang nie.

Dit het verder geblyk dat Simplesse® 'n hoogs suksesvolle vetvervanger in hoëveselmuffins is. Die hoëveselmuffins is as hoogs aanvaarbaar deur dieetkundiges en verbruikers geëvalueer. Die analitiese paneel het slegs klein verskille tussen die eksperimentele muffins en die volvet kontrolemuffins aangedui. Verskille van die kontrolemonster het egter nie outomaties geïmpliseer dat die muffins onaanvaarbaar vir verbruikers was nie.

LIST OF ABBREVIATIONS

AMP	aerobic mesophilic plate count
ANOVA	analysis of variance
BMI	body mass index
CDL	chronic diseases of lifestyle
CFU/g	colony forming units per gram
CHD	coronary heart disease
ERH	equilibrium relative humidity
FACT	food action rating test
FAO	Food and Agriculture Organization of the United Nations
FBDG	food-based dietary guidelines
HDL	high-density lipoprotein cholesterol
LDL	low-density lipoprotein cholesterol
MANOVA	multivariate analysis of variance
NIDDM	non-insulin-dependent *diabetes mellitus*
NFMS	non-fat milk solids
RDA's	Recommended Dietary Allowances
WHO	World Health Organization
WPC	whey protein concentrate

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CHAPTER 1

INTRODUCTION

INTRODUCTION

1.1 BACKGROUND AND MOTIVATION

This study was motivated by a need for more baked products that could be included in low-fat, high-fibre diets. These diets are known to decrease the risk of chronic diseases of lifestyle (CDL). This chapter will provide a brief overview of the relationships of fat and fibre with CDL. The incorporation of this knowledge into dietary advice to the public and the difficulties experienced with compliance to low-fat, high-fibre diets will be discussed, and the use of fat substitutes or replacers as a possible solution to this problem will then be motivated. The objectives of this study and the methods followed will be outlined briefly, after which the structure of the thesis will be explained.

1.1.1 Relationship between diet and chronic diseases of lifestyle (CDL)

The evidence linking diet with CDL, also known as the preventable, non-communicable diseases, is recognised internationally. Rather than establishing a causal link, the evidence to date, more appropriately, defines a strong association/relation between diet and many CDL. Globally, these diseases are major causes of illness and death. Those diseases that are thought to have a nutrition component in their aetiology and for which some form of prevention is likely to be applicable are coronary heart disease (CHD) and underlying atherosclerosis and hypertension, cerebro-vascular disease (stroke), some forms of cancer, non-insulin-dependent *diabetes mellitus* (NIDDM), obesity, osteoporosis, non-cancer disorders of the large bowel and nutritional anaemias (Lester, 1994:203). CDL are also among the leading causes of death among all groups of South Africans, including the black population. According to Bradshaw *et al.* (1995:7) stroke was the third most frequent cause of death while CHD was the cause of 9698 (4,86%) deaths in South Africa in 1990. Studies by Steyn *et al.* (1992:229) showed that 56,5% of all South Africans aged 15-64 years need to change their lifestyle in order to reduce their risk for CDL.

1.1.1.1 Relationship between fat and CDL

As a concentrated source of energy, excess fat leads to an increase in fat stores and promotes the development of obesity which has significant health consequences (Ravussin & Tataranni, 1997:542). On the other hand, certain saturated fatty acids (lauric, myristic and palmitic acid) and trans-fatty acids definitely raise serum cholesterol (low-density lipoprotein cholesterol – LDL) levels which increase the risk of cardiovascular diseases such as CHD and stroke. Higher intakes of unsaturated fatty acids may also promote obesity which has multiple effects on serum cholesterol and lipoproteins (Grundy, 1996:54). Strong epidemiological evidence also exists for a positive relationship between obesity and blood pressure. Obesity raises LDL-cholesterol, it lowers HDL-cholesterol and correlates with high blood pressure which all increase the risk for CHD (Grundy, 1992:474; Ernst *et al.*, 1997:S47). Greater fat intake as a major cause of obesity is also associated with the development of progressive insulin resistance which is one of the causal factors of NIDDM. The risk of developing NIDDM in adults with a body mass index (BMI) of >30 kg/m^2 (obesity) is five times that of adults with a BMI of <25 kg/m^2 (James & Pearson 1993:522; Garrow, 1993:467). Ecological studies over the past 30 years have demonstrated the correlation of greater fat intake with increased risk and higher mortality due to various cancers such as colon, prostate, uterus, endometrium and ovarian cancer. Higher fat intake may also heighten the risk of breast cancer, firstly through increased blood estrogen levels, and secondly through increased obesity (Kuller, 1997:S9).

1.1.1.2 Relationship between fibre and CDL

In a recent review of the relationship between fibre and CHD, Jenkins *et al.* (1998:633) comes to the following conclusion: "Epidemiological studies support a negative association between dietary fibre intake and risk of CHD. For the most part, the association has been with insoluble fibre, especially wheat bran. However, viscous fibre sources are likely to play a role since they reduce lipid risk factors for CHD including total and LDL-cholesterol and apolipoprotein B by increasing faecal bile acid losses. In addition, soluble fibre may reduce the rate of nutrient absorption so altering chylomicron synthesis and reducing postprandial glucose and insulin levels and other risk factors for CHD. There is also evidence that some insoluble fibers might alter serum lipids and improve carbohydrate tolerance but these phenomena need to be confirmed and other mechanisms explored, including improved clotting and thrombolytic factors and increased antioxidant status". In addition to its protective effects against CHD, there is

agreement in the literature that wheat fibre and therefore all whole-wheat products, play an essential role in protecting against constipation and related bowel diseases (Cummings, 1993:497; Vorster *et al.*, 1990:343). According to Anderson *et al.* (1994:1242S) high fibre intakes and fibre rich foods are also associated with enhanced weight control, better glycemic control and reduced risk of certain forms of cancer. As concluded by Gallaher and Schneeman (1996:88), associations between disease risk and dietary factors are, however, multifactorial and present knowledge indicates that fibre should not be isolated as a single factor affecting risk but must be evaluated in the context of the total dietary pattern.

1.1.2 Dietary goals and guidelines

In his review on the evolution of dietary guidelines, Truswell (1987:1062) argues that, contrary to the Recommended Dietary Allowances (RDA's), dietary guidelines or goals do not primarily aim to provide enough of the essential nutrients, but are formulated to reduce the chances of developing CDL and to improve overall nutritional well-being and quality of life. They do not deal with energy requirements but with optimal proportions of the energy-yielding proximate dietary components. As a consequence of increased risk of CDL related to high-fat intake and the mounting evidence of the overall health benefits of high-fibre diets, aggressive efforts should be made to incorporate goals in nutrition guidelines for health promotion (Truswell, 1987:1062; Schrimshaw, 1990:90). Dietary guidelines regarding fat and fibre formulated for South Africa also recommend the following: total fat intake should be less than 30% of energy (% E), saturated fat intake should not be more than 10% E, polyunsaturated fat intake should not exceed 10% E (1:1:1), dietary cholesterol intake should be < 300 mg per day and fibre-intake should be between 20 and 30 g per day (Diet Consensus Panel, 1989:591).

These dietary guidelines should, however, be translated into foods since consumers think in terms of foods rather than nutrients. The purpose of using food-based dietary guidelines (FBDG) is to improve current dietary practices and prevailing diet-related public health problems by focussing on locally available foods instead of nutrients. Currently available food supplies could even be altered by changes in food demand. The greatly increased consumer demand for low-fat foods in response to FBDG, is a good example (WHO/FAO: 1996:84). Therefore, FBDG can assist the total population to eat an adequate but also a prudent high-fibre, low-fat diet.

1.1.3 The problem

Despite an increased awareness of health and a slight change in consumer dietary practices, it remains difficult to achieve the above-mentioned dietary recommendations. Compliance with prudent guidelines by South Africans is disappointing (Vorster *et al.*, 1995:119). People seem to like the texture, flavour and desirable mouthfeel of high-fat foods. According to Mela and Marshall (1991:44) the sensory attributes contributed by fats are a critical factor in the acceptance and consumption of many foods. Because few low-fat products that satisfy the sensory preferences of consumers exist, it is difficult to limit or to reduce the fat content of a diet (Drewnowski, 1992:17). Food scientists have been searching for ways to reduce the fat content of products and to provide feasible fibre carriers without influencing the acceptability of these products (Vratanina & Zabik, 1978:1590). The food industry also faces a big challenge to provide needed high-fibre, low-fat products for the Prudent Diet. Enrichment of baked products by addition of high-fibre cereal grain components such as wheat bran and barley shorts is one way to increase fibre intake (Newman *et al.*, 1998:23; Sosulski & Wu, 1988:186). Experience has demonstrated, however, that fibre-enriched baked products require increased amounts of fat to maintain tenderness. Simply removing or reducing the fat can have a profound impact on the sensory characteristics of and consumer preferences for most foods (Lindley, 1993:101). Baked products are of special interest because fat performs a major role in the eating quality and storage stability of these products (Conforti *et al.*, 1996:285). Fat serves several textural functions in baked products such as tenderness, moistness, mouthfeel, richness and lubricity (Yackel & Cox, 1992:146). Fat contributes flavour, interacts with flavour components for sensory balance and precursors to flavour formation, blends flavours and masks off-flavours (Schirle-Kellar *et al.*, 1992:1448). Achieving flavour or texture parity with full-fat baked products is difficult in fat-free systems. The presence of fat also extends the period during which the crumb of cakes feels fresh and moist by inhibiting the premature loss of moisture and volatile flavour materials, implying that reduction of the fat content would also reduce shelf life (Tamstorf *et al.*, 1985:77; Pyler, 1998:980).

1.2 THE USE OF FAT SUBSTITUTES/REPLACERS AS A POSSIBLE SOLUTION

The food industry's most recent and innovative attempt to reduce dietary fat is the introduction of redesigned and new ingredients as fat substitutes or fat replacers. These new ingredients can help food manufacturers to reformulate traditional high-fat food products into good-tasting, acceptable, reduced-fat alternatives (Miraglio, 1995:1175S). Many terms are used to describe this diverse group of ingredients either as synonyms or to distinguish among them. For the purpose of this thesis, the inclusive term fat substitute or replacer will be used synonymously when referring to ingredients that replace some or all of the functions of fat and may or may not provide nutritional value. These substitutes contain either no or far fewer kilojoules than traditional fats (Ruoff, 1991:1237). Although there is a tendency among consumers to consider fat substitutes as a homogenous group, they clearly represent a wide range of chemical sources with a diverse array of sensory and functional properties (Hassal, 1993:142). The main approach to classifying these products is based on the chemical nature and origin of the product along with the energy value. A summary of a classification of some current and proposed fat substitutes broadly grouped into either protein-based, carbohydrate or lipid-based materials and blends with some food applications is listed in Table 1. Most of the protein and carbohydrate-based fat substitutes yield reduced-kilojoule products because of their lower energy density compared with that of fats and oils. Cellulose and certain gums are resistant to digestion except by bacteria in the lower intestine; consequently their kilojoule (kJ) contents are negligible (Glueck *et al.*, 1994:1613). Lipid-based fat substitutes such as olestra achieve their reduced-kJ functionality primarily by resistance to digestive lipases, which makes these compounds unavailable for absorption. Emulsifiers and fat extenders contribute less energy because a smaller amount is needed to produce fat-like characteristics (Hassel 1993:142).

As concluded by Setser and Racette (1992:293), a universal fat substitute simply does not exist. All of the macromolecule replacers contribute distinct properties suitable for replicating a limited number of functions of fat in particular food products. In spite of consumers' demand for healthier products, nutritional attributes are not the sole determinants of the success of a food product, because marketing studies indicated that consumers are unwilling to compromise on taste. Without good flavour, texture, mouthfeel and appearance, the product will be deemed unacceptable by the consumer.

TABLE 1.1: CLASSIFICATION AND APPLICATION OF FAT SUBSTITUTES IN FOODS*

Category/Type	Trade names	Source	Application in food	kJ/g
1. PROTEIN-BASED				
Microparticulated protein	Simplesse® Dry 100	Whey protein concentrate	Frozen desserts, ice cream, cultured dairy products, process cheese, baked goods, puddings, salad dressings, soups, dips and spreads	5,6 kJ/g hydrated
	Simplesse® Dry 500	Whey protein concentrate		5,6 kJ/g hydrated
	Simplesse® Dry 300	Egg white and milk protein	Cold applications – ice cream, cheese, yoghurt, low-fat spreads, salad dressings, baked products	4-8 kJ/g
	Dairy light™/ Dairy Lo™	Milk-derived solids/ sweet milk whey concentrate	Frozen dairy desserts, yoghurt, sour cream, sauces and dips	16,8 kJ/g
	Lita®	Zein (com. Protein)	Frozen desserts and baked goods	6,3 kJ/g
2. CARBOHYDRATE- BASED				
Starch derivatives:	Amalean 1 N-Lite LP	Modified high amylose corn starch	Cakes, cheese, sour cream, yoghurt, dairy desserts, frozen dairy desserts, salad dressings, dips, margarine, instant breakfast drinks, mayonnaise, sauces, gravies, soups, peanut butter, high-fibre bread, cookies, cereals, processed meats	14-16,8kJ/g
Modified starches	N-Lite L Sta-Slim	Modified waxy corn		
	N-Oil® 11 N-Lite CM	Modified tapioca		
	Maltrin® Stellar™	Modified corn		
	Paselli® BC Sta-Slim™	Modified potato		
	Rice-trin Remygel	Modified rice		
	Oatrim Slenderlean	Modified oats		
Maltodextrins	Dairytrim	Oat flour	Fat replacer or bulking agents	4-16 kJ/g
	Oatrim 5	Oat maltodextrin		
	Novadex 120	Oat flour	Puddings	
	Instant N-Oil	Tapioka maltodextrin	Margarine, imitation sour cream, salad dressings, frozen desserts, cheese, cereals, snacks	
	Maltrin® M N-Lite D	Corn maltodextrin		
	Star Dri-1 Lycadex®	Corn	Soups, cheese cakes, ice cream, cheese spread	16,8 kJ/g
	N-Lite B	Waxy corn (maize)	Bakery products, dips, salad dressings, frostings, frozen desserts, mayonnaiselike products, table spreads, meat products, confections.	
	Rice Trin 3	Rice maltodextrin		
	Paselli® SA2 Lycadex®100	Potato maltodextrin		

Category/Type	Trade names	Source	Application in food	kJ/g
Polydextrose	Litesse™	Modified glucose polymers with sorbitol and citric acid	Bakery goods, candy, frozen desserts, yoghurt, dairy products, chewing gums, salad dressing.	4,2 kJ/g
Cellulose derivates	Avicel® Novagel NC200 Fibrex® Fibrim®	Microcrystalline cellulose Hemicelluloses (sugar beets) Hemicelluloses (soy)	Frozen desserts, dairy products, salad dressings	0
Hydrocolloids (gums)	Avicel® RCN-15 Carrafat Avicel® RCN-30 Slendid Fibercel	Cellulose + guar gum Carrageenan Cellulose + xanthan gum Pectin (citrus peal)	Ice cream, frozen desserts Low-fat sausages and beefburgers Fat-reduced/free salad dressings, soups, cakes, cookies, processed cheeses, yoghurts, whipped toppings	0-14 kJ/g 4 kJ/g
Altered sugars	Raftiline	Inulin	Ice cream, candy, bakery goods	
3. LIPID/FAT-BASED (synthetic or structured fat compounds)				
Fatty acid esters of sugar and sugar alcohols	Olestra Crisco Puritan	Sucrose-polyester Sucrose-polyester Sucrose-polyester	Frying & baking, savoury snacks, ice cream and cheese	kJ free
Caprocaprylobehenin	Caprenin® Salatrim®	Glycerol & caprylic, capric and behenic acid Hydrogenated Canola oil	Replace cocoa butter in candy bars and chocolate coatings (kJ reduced triglyceride)	20 kJ/g
Alkyl glyceryl ethers	NR	Tri-aloxyglyceryl ether Dialkyl glycerol ether Glycerol monoester diether	NR	
Polycarboxylic acid and propoxylated glyceryl esters	EPG DDM TATCA	Esterified propoxylated glycerol Dialkyl dihexadecyl-malonate Tri-aloxy tri-carballyates	High or cold temperature applications - ice cream, toppings & sauces, salad dressings, mayonnaise High temperature application - frying of potato & corn chips Margarine and mayonnaise	0 0 0
Fat extenders	Emulsifiers		Bakery products, cake mixes, frozen desserts and icings	10-38 kJ/g

Category/Type	Trade names	Source	Application in food	KJ/g
4. BLENDS				
	Prolestra™/Colestra™ Trailblazer Bindtex ™ Veri-Lo® fat extender	Sucrose polyester + protein Egg albumen + Xanthan gum Carrageenan + dairy prot. Emulsion of fat from soybean oil/milkfat with polydextrose	Ice cream, salad oils, mayonnaise, baked products Frozen desserts Low-fat meats Fat-free mayonnaise, salad dressing	<16 kJ/g
	N-Flate	Mono- en diglyceride emulsifiers + modified starch, guar gum and non-fat milksolids	Baked products such as cakes and cookies	21 kJ/g
	Nutrifat™ Nutrifat C Finesse™ Instant PC PC Supreme	Hydrolised starches + protein	NR	NR
	Ultra-Freeze 400®	Modified food starch, vegetable protein and corn syrup solids	NR	NR
Simplesse® bakery blends (Simplesse® + emulsifiers)	Simplesse Bakery Blend 710 (21% fat)	Whey protein concentrate with monyglycerides and sodium stearoyl lactylate	Cakes, muffins and sweet dough	21 kJ/g
	Simplesse Bakery Blend 720 (31% fat)	Whey protein concentrate with propylene glycol monoesters, monoglycerides and sodium stearoyl lactylate	Cakes, muffins and sweet dough	19,5 kJ/g

NR: not reported

(Adapted from Weisenfeld 1995; Miraglio 1995; Nutrasweet Kelco 1995; Glueck *et al.*, 1994; Tamime *et al.*, 1994; Hassel 1993 & Setser & Racette 1992)

1.2.1 Simplesse®

Simplesse®, an all natural fat substitute is a versatile and highly functional fat replacer made from whey protein concentrate (WPC) that has been microparticulated using a patented process (US Patent #4,734,287; Singer & Dunn, 1990). The resulting microparticulated protein particles are small in size (0,1-2,0 microns), spheroidal and deformable, creating the sensation of creaminess and fat-like mouthfeel in a variety of applications (Harrigan & Breene, 1989:266). Protein quality assessed on the basis of protein efficiency ratio (PER) and amino acid analysis show that Simplesse® is nutritionally the same as WPC (Corliss, 1992:1). According to Sampson and Cooke (1992:963), there is no evidence that the microparticulated proteins of Simplesse® possess any novel antigens or cause increased immunologic activity when compared to cow's milk and egg protein. Simplesse® is available in three forms, as free-flowing powders (Dry 100 and Dry 500) and as a viscous liquid (Simplesse® 300), and offers advantages over WPC in its effect on texture mouthfeel and flavour (The NutraSweet Kelco Co, 1995). In this thesis the term Simplesse® refers to Simplesse® Dry 100. Simplesse® furnishes only 5,6 kJ/gram when hydrated. Each gram of Simplesse® hydrated in 2 g of water can replace 3 g of fat, which implies a considerable energy reduction (Gershoff, 1995:306). Simplesse® addresses key functional aspects of fat reduction during development of a variety of reduced-fat products such as frozen desserts, ice cream, cheese, sour cream, salad dressings, dips, spreads, soups and mayonnaise (Table 1).

In baked goods, Simplesse® provides several functions of fat, such as the same tenderness, moist mouthfeel, chewiness and desirable flavour and even enhanced surface browning, increased batter viscosity, aeration and greater finished-product volume than the full-fat counterpart (Corliss, 1992:4). Because Simplesse® is a protein, it exhibits both hydrophilic and hydrophobic properties and performs as an emulsifier in baked goods. According to Schirle-Keller (1994:815) foods with Simplesse® should have a flavour profile similar to fat containing products because Simplesse® interacts with flavour compounds more like oil than any of the other fat substitutes, easing the task of flavour balance in low-fat systems. Reduction of fat/oil content reduces the opportunity for rancid off-flavours to develop during storage and can increase the shelf life of the product (Civille 1990:428). Some general suggestions from the NutraSweet Co. (1994) for formulating reduced-fat baked products with Simplesse® are: adjust the amount and type of flour used; increase the water added; remove whole eggs and non-fat dried milk; add yellow colour to replace yolk colour. According to Civille (1990:427) the use of

Simplesse® as a fat substitute in baked goods offers an opportunity to develop healthier alternatives for consumers which are lower in fat and with little or no sensory sacrifice, which means greater compliance with prudent guidelines.

1.3 OBJECTIVES OF THIS STUDY

1.3.1 Main objective

The main objective of this study was to develop and to evaluate the sensory and physical characteristics, acceptability and storage stability of low-fat, high-fibre muffins, using various levels of Simplesse® as a fat substitute.

1.3.2 Specific objectives

1.3.2.1 To develop a high-fibre (> 7%) muffin which contains less than 3 g total fat per 60 g serving size with sensory qualities comparable to the full-fat control muffin.

1.3.2.2 To compare the effect of zero, 80 and 100% replacement of oil with Simplesse® Dry 100 on the sensory and compositional characteristics of freshly baked high-fibre muffins.

1.3.2.3 To compare the sensory characteristics of high-fibre muffins in which oil was replaced with non-fat milk solids with muffins containing Simplesse®.

1.3.2.4 To investigate dietitians' awareness and knowledge regarding fat substitutes such as Simplesse®.

1.3.2.5 To inform dietitians about the characteristics and application of fat substitutes such as Simplesse®.

1.3.2.6 To assess dietitians' acceptance of, preference for and consumption intent regarding high-fibre muffins containing various levels of Simplesse®, using hedonics and food action rating scales.

1.3.2.7 To develop and apply an attitude scale to determine the attitude of dietitians towards the problematic aspects of reducing fat in the diet, advantages of fat substitutes in the diet and the need for using Simplesse®.

1.3.2.8 To assess the effect of partial and total oil replacement with Simplesse® on consumer acceptance of, preference for and intended consumption of high-fibre muffins.

1.3.2.9 To determine which of the selected weight control variables influenced consumers' acceptance or intended consumption.

1.3.2.10 To evaluate and compare the effect of different percentages of oil replacement with Simplesse® on the sensory and physical characteristics of high-fibre muffins freshly baked, stored at room temperature for 24 h or frozen and thawed, respectively, within each storage period and within each formula.

1.3.2.11 To evaluate and to compare the effect of different percentages of oil replacement with Simplesse® on the sensory, physical characteristics and microbiological counts of high-fibre muffins freshly baked from either freshly prepared batter or batter refrigerated for 24 h or 48 h respectively, within each period of batter refrigeration and within each formula.

1.4 METHODOLOGY

1.4.1 Step 1: Pilot study

1.4.1.1 Development of appropriate wheat bran muffin formula

- Formulas of wheat bran muffins (± 5% fibre) were identified, prepared and evaluated.
- Characteristics of high-fibre muffins were defined.
- Two formulas were chosen and fibre content increased to 4,5 g fibre/60 g baked muffin (> 7% fibre).
- Oil was substituted at different levels in both formulas. The best results were obtained using 5% Simplesse® for 80% oil replacement and 8% Simplesse® for 100% oil replacement.

Additional liquid in the proportion of 1,43 parts of water to each part of Simplesse® was added to rebalance the formula.

- Both formulas were prepared with different levels of fat replacement and evaluated by experienced food scientists. The formula that gave the best quality muffins as defined by the "experts" was chosen as the experimental control formula.

1.4.1.2 Training of the descriptive sensory panel

Eight panellists were selected from an existing analytical sensory panel previously screened and trained, according standardised methods (Stone & Sidel, 1985; Heymann, 1990 & 1995; Meilgaard *et al.*, 1991). This panel frequently participated in sensory projects within the Department of Nutrition and Family Ecology. Panellists were selected on the basis of their willingness to participate, long-term availability and prior experience with sensory evaluation of baked products. Panellists were trained to evaluate the sensory characteristics of muffins in eight, one-to-two hour sessions over a two-week period. Muffin references, representing a wide spectrum of attributes at various intensities prepared by varying the ingredients and preparation methods to create various external and internal characteristics, were used. In the first sessions the panellists were oriented to the basic concepts of generic descriptive analysis and were asked to evaluate the sensory differences among the samples by using a combination of the consensus and ballot methods, deriving some descriptors on their own through consensus while others were added by means of a sample rating-sheet (ballot). Initially, panellists focussed on one or two specific characteristics at a time. Later all the attributes were evaluated by presenting samples of increasing difficulty in discrimination. The panellists finally defined the characteristics of high-fibre muffins and refined the rating-sheet used in the initial research (see addenda). Performance evaluation was conducted by serving a set of two duplicate samples (4), which the panel leader knew to be different, to each panellist on four occasions to assess consistency and to determine the coefficient of reliability of the taste panel and for each panellist for each sensory attribute (Setser, 1993; Winer *et al.*, 1991:1014). Concern about using some hedonic terms such as "rich dark golden brown crust colour", using one scale for evaluating two different attributes and some confounded scales where a score of 1 indicated defects going in two directions used during the initial research (see chapter 2), necessitated further training of the panellists (Setser, 1994). This training included revising and defining attributes with anchors representing minimum (1) and maximum (6) intensities in order to avoid confounded data (Table 1, chapter

5). This training, based on the methods proposed by Lawless and Heymann (1998), equipped the panel to evaluate the muffins as indicated in chapter 5. At a later stage, after personal communication with Prof. Carole Setser, it was decided to repeat the assessment of crust and crumb colour (lightness) and to evaluate some additional attributes (included in Table 1), namely mouthfeel (crumb moistness), sweet taste and nutty taste as shown in chapters 5 and 6.

1.4.1.3 Standardisation

During the pilot study all the methods and techniques regarding muffin preparation, serving, sensory evaluation, physical tests and chemical analysis were standardised. A trained technician baked all the muffins used in the study.

1.4.2 Step 2: Final study

In this part of the study the objectives as stated in 1.3 were reached. Every sub-study was published and is given as a separate chapter (chapters 2-6) in this thesis. The methods used in each sub-study are described in each publication.

1.5 STRUCTURE OF THIS THESIS

As indicated above, this thesis consists of published papers representing the different steps followed in the development and evaluation of the low-fat high-fibre muffins. Following this introductory chapter, chapter 2 describes the characteristics of high-fibre muffins containing various levels of fat substitute. In the following chapter (chapter 3) dietitians' attitude towards fat substitutes and the acceptability of high-fibre muffins containing Simplesse® is discussed. In chapter 4 consumer acceptance of, preference for and consumption intent of high-fibre muffins containing Simplesse® is reported. The effects of oil replacement and storage were reported in chapter 5 while chapter 6 provides the effects of batter refrigeration on the characteristics of high-fibre muffins with a protein-based fat substitute. Chapters 2, 3 and 4 have been published while chapter 5 is currently (Nov 1998) in press and chapter 6 is submitted (South African Journal of Family Ecology and Consumer Sciences). Standard deviations are not shown in the different tables because of the complexity of these tables. However, standard deviations were used to calculate significant differences and are available on request. Chapter 7 is a combined discussion of all the results from chapters 2-6 as well as conclusions and

recommendations on application of results and further research. Chapter 7 is followed by the addenda, which include the rating-sheets and questionnaires used in the different chapters, as well as the final formulas and compositions of the three muffins developed in this project.

It should be noted that this thesis does not contain a separate literature survey because the appropriate and relevant literature has been discussed and is given in each separate chapter or publication (chapters 1-7). Relevant references are also given at the end of each chapter and all questionnaires are included as addenda.

Note that due to the structure of the thesis consisting of published articles and unpublished material, the style sheets used in these two categories differ. The published articles and the articles in press adhere to the style sheet prescribed by the specific journal, while the unpublished material adheres to the mandatory style sheet stipulated by the Potchefstroom University.

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CHAPTER 2

CHARACTERISTICS OF HIGH-FIBRE MUFFINS CONTAINING VARIOUS LEVELS OF FAT SUBSTITUTE

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Characteristics of high-fibre muffins containing various levels of fat substitute

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Abstract

There is a great need for high-fibre low-fat food products of high quality for the Prudent Diet. Simplesse®, a protein-based fat substitute, formulated from milk whey proteins, provides an opportunity to develop low-fat products. The effect of zero (control), 80 % (Formula COS) and 100 % (Formula CS) replacement of oil with Simplesse® on the sensory and compositional characteristics of high-fibre muffins was evaluated. Additional controls (Formulas COM and CM) in which oil was replaced with non-fat milk solids (NFMS) were included. Formula had a statistically significant effect ($p \leq 0.001$) on all the characteristics. The muffins with 80 % oil replacement with Simplesse® (COS) were scored significantly higher, more favourable on crust shape, gloss, colour and surface but did not differ significantly from the full-fat control on crumb colour, cell distribution, cell size, crust toughness, adhesiveness and flavour. The full-fat control muffins, however, were significantly more tender and compressible and less cohesive than the experimental muffins with Simplesse® although the latter were still tender. Muffins of Formulas COM and CM differed significantly from the full-fat control muffins and the muffins with Simplesse® with regard to all the sensory characteristics and were found to be inferior in quality. It was concluded that Simplesse® Dry 100 can successfully replace up to 100 % of the oil in high-fibre muffins, in which case the fat content can be reduced by as much as 84 %.

Key words: Muffins, high-fibre, fat substitute, Simplesse®

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Uittreksel

Daar bestaan 'n behoefte aan hoë-vesel, lae-vet produkte van hoë kwaliteit vir die Omsigtige Dieet. Simplesse®, 'n proteïengebaseerde vetvervanger, maak die ontwikkeling van lae-vet produkte moontlik. Die effek van die vervanging van 80 % (Formule COS) en 100 % (Formule CS) olie met Simplesse® op die sintuiglike eienskappe en samestelling van hoë-vesel kontrole muffins (Formule C) is ondersoek. Muffins waarin die olie met vetvrye melkpoeier vervang is, is as addisionele kontroles (Formules COM en CM) ingesluit. Formule het 'n statisties betekenisvolle effek ($p \leq 0.001$) op al die eienskappe getoon. Die muffins waarin 80 % van die olie met Simplesse® vervang is, is betekenisvol hoër geëvalueer ten opsigte van bokorsvorm, -glans, -kleur en -oppervlak as die kontrole, maar het nie statisties betekenisvol ten opsigte van kruimkleur, selverspreiding, selgrootte, korstaaiheid, klewerigheid en smaak verskil nie. Die kontrole muffins sonder vetvervanging was egter betekenisvol sagter, meer saamdrukbaar en minder saamklewend as die muffins met Simplesse®, alhoewel laasgenoemde steeds sag was. Die muffins waarin die olie met vetvrye melkpoeier vervang is, het betekenisvol van die kontrole ten opsigte van al die sintuiglike eienskappe verskil en is as laer in kwaliteit geëvalueer. Daar is tot die gevolgtrekking gekom dat Simplesse® Dry 100 tot 100 % van die olie in hoë-vesel muffins suksesvol kan vervang, in welke geval die vetinhoud met soveel as 84% verminder kan word.

Introduction

A high-fibre low-fat diet is one of the environmental factors which protects humans against chronic degenerative diseases of life style, such as coronary heart disease, obesity and some forms of cancer[1,2]. According to dietary guidelines total fat-intake should be restricted to less than 30% of total energy[3] and fibre-intake should be at least 20-30 g/day for healthy people[1]. Drewnowski (1990)[4] stated, however, that the trend towards increased consumption of high-fat food will be difficult to reverse without new technologies to create foods that mimic the pleasurable aspects of high-fat foods. The use of fat substitutes as alternative ingredients, such as microparticulated protein, provides an opportunity to develop healthier products, lower in fat, with sensory properties comparable to the full-fat counter-products[5,6].

Simplesse®, a low kilojoule protein-based fat substitute, recently approved for use in food products, is formulated from milk whey or egg white protein. Because water molecules are incorporated by hydration during processing, one gram of Simplesse® furnishes only 5.6 kJ compared to the 16.8 kJ normally furnished by a gram of protein. By replacing one gram of fat (38 kJ) by one gram of Simplesse® the total energy reduction is considerable[7,8].

Fat is important in baked products. It tenderises the product and prevents tunnel formation in muffins. Fat absorbed on surfaces of gluten proteins interferes with hydration and thus with the development of a cohesive gluten structure[9]. Addition of fat improves keeping quality and ensures that baked products such as muffins are moist, with a fine, more uniform crumb texture with thin cell walls and a richer flavour[10,11,12]. It is therefore evident that fat performs specific functions in baked products and a successful fat substitute should be able to replicate

these functions. According to Corliss (1992)[13], baked products made with Simplesse® exhibited the same tenderness, moistness and desirable flavour as full-fat products and even enhanced surface browning.

Schönfeldt (1987)[14] stated that there is a need for standardised formulas developed by food scientists for high-fibre products with a known dietary fibre content. Experience demonstrated, however, that high-fibre products require special formulation to ensure good eating quality. To produce high-quality, reduced-fat products, more consideration must be given to the effects of the substitution on the sensory properties of the finished products[15]. In selecting a high-fibre product, muffins are a good choice because muffins are well-known[16] and widely used by subjects who need to follow a low-fat diet. Muffins are also convenient, easy to prepare[14] and its composition makes it easy to add fibre to the diet[17]. According to results from a preliminary study high-fibre muffins, however, seem to require increased amounts of fat to maintain tenderness. This fat could possibly be reduced by using Simplesse®.

The main objective of this study was to develop a high-fibre (>7%) muffin which contained less than 3% total fat per 60 g serving size with sensory qualities comparable to the full-fat control muffin. Secondly, to evaluate the effect of zero, 80 and 100% replacement of oil with Simplesse® Dry 100 on the sensory and compositional characteristics of high-fibre muffins. The replacement of oil at the same levels with non-fat milk solids (NFMS) was also investigated during the study as a control to determine whether milk proteins, such as NFMS, could be used successfully instead of Simplesse®.

Materials and methods

The experimental design for this study is shown in Figure 1.

Muffin formulations and preparation

During a pilot study ten wheat bran muffin formulas relatively high in fibre (± 5%) were identified, prepared and evaluated according to the characteristics for high quality bran muffins[18,19]. Two formulas were chosen and the fibre content of each was increased so that both provided at least 4.5 g fibre / 60 g baked muffin (> 7% fibre). A more pleasant and nutty flavour was obtained with higher levels of wheat bran by baking the wheat bran at 100 °C for 4 h before mixing. During the following phase the oil was substituted in both formulas. In the case of 80% fat substitution 5% Simplesse® and for 100% substitution 8% Simplesse® gave the best results. According to the recommendations by Nutra-Sweet, Simplesse®Dry 100 could be added either dry to the dry ingredients and sifted thoroughly or in hydrated form to the liquid phase. Both alternatives were tested and the first option gave the best results. Additional liquid in the proportion of 1.43 parts of water to each part of Simplesse® was added to rebalance the formulas. The muffins of both formulas were evaluated by experienced food scientists and the formula that gave the best quality muffins was chosen as the experimental control formula. A trained technician produced all muffins used in the study.

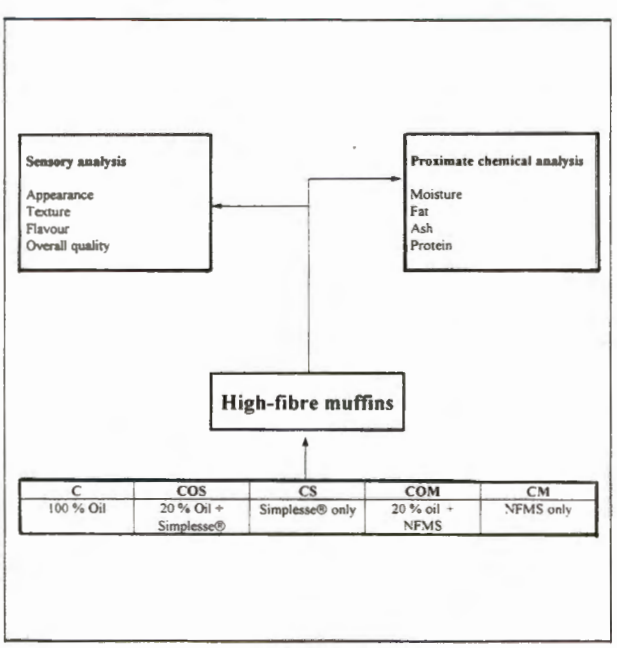

FIGURE 1: Experimental design

The formulations and sources for ingredients for the full-fat and reduced-fat high-fibre muffins used in this study are given in Table 1. Each of the ingredients, except eggs and yoghurt, was from a single lot or was purchased in separate lots at the start of the study and mixed together so that aliquots could be taken from the composite batch. Fresh eggs and yoghurt were purchased weekly from a local supermarket. Ingredients, except for eggs, were weighed 2-3 h before mixing and baking. Eggs were beaten slightly and weighed immediately before mixing. During mixing an adjusted muffin method was used to improve the flavour of the muffins. The baked wheat bran was hydrated in warm water for 5 min and the bicarbonate of soda dissolved in the yoghurt and then combined with the liquids before it was mixed into the dry ingredients. Because bran interferes with the development of gluten, the effects of increased mixing are less pronounced than in plain muffins. The batter was mixed only until well moistened but still lumpy (20 strokes), covered with clear polyethylene plastic wrap and left at room temperature to hydrate for 1 h . Batter samples (70 g) were scooped and weighed into each cup of a standard 12 count aluminium muffin pan (Tala, 50 mm diameter x 30 mm depth) which had been sprayed with a non-stick spray (Spray and Cook, Coleman). All muffins were baked in a preheated oven (Defy model 420) for 20 min at 180 °C. Following a 5 min setting period, the baked muffins were removed from the pans and allowed to cool on wire racks for 1 h before being stored in plastic bags at room temperature until sensory, physical and chemical measurements were conducted on the same day. All the formulations yielded at least 12 baked muffins of 60 g each per batch.

Sensory analysis

An analytical descriptive panel (8 panelists) was trained to evaluate the quality characteristics of high-fibre muffins in eight 1-2 h training sessions over a two week period using muffin references prepared by varying the ingredients and mixing methods to create various external and internal characteristics. Panelists were selected on the basis of their willingness to participate, availability and their familiarity with baked goods. Performance evaluation to evaluate the training of the panel and each panelist provides reliability coefficients between 0.5170 - 1.000 which indicated adequate training[20]. Criteria and attributes for high quality high-fibre muffins were defined (Table 2)

TABLE 1: High fibre muffin formulations – Baker's percentage

			Formulations				
Constant ingredients	**Flour mass%**	**Variable ingredients**	**Control 100% oil**	**COS 20% oil + Simplesse**	**CS Simplesse only**	**COM 20% oil + NFMS**	**CM NFMS only**
Wheat bran[a]	86.7	Water	133.3	180	206.7	180	206.7
Granulated white sugar[b]	100.0	Sunflower oil[i]	66.7	13.3	–	13.3	–
Fresh egg[c]	33.3	Simplesse®[j]	–	33.3	53.3	–	–
Yoghurt[d]	166.7	Non-fat milk solids (NFMS)[k]	–	–	–	33.3	53.3
Bicarbonate of soda[e]	3.3						
Whole wheat flour[f]	50.0						
Cake flour[g]	50.0						
Salt[h]	1.7						

a Digestive bran, Snowflake, Premier Foods
b Illovo Ltd
c Grade 1, Top Lay
d Low fat plain Swiss style, Clover
e Royal, Royal Beech-Nut
f Nutty wheat, Snowflake, Premier Foods
g Snowflake, Premier Foods
h Iodised, Cerebros
i Excella, Senwesko
j Simplesse® Dry 100, Simplesse Co., Deerfield, IL
k Elite, fat free instant milk powder, Clover SA

TABLE 2: Characteristics of high-quality high-fibre muffins as defined by the descriptive panel

APPEARANCE	
Top crust shape	Symmetrical, even, well risen, good volume Slightly rounded, no peaks
Crust gloss	Matt to slightly glossy
Crust and crumb colour	Even, rich dark golden-brown, no light specks
Crust surface	Pebbled, coarse appearance rather than smooth or too rough
TEXTURE	
Cell distribution	Even, without tunnels
Cell size	Medium size round cells with medium thin cell walls
Compressibility	Require little force to compress slightly between fingers
Cohesiveness – at initial bite	Loose, not cloggy at all
Cohesiveness – after chewing	Loose, not cloggy at all
Crust toughness	Firmer than the crumb, but not tough
Tenderness	Loose, tender and slightly moist
Adhesiveness	Do not stick to the teeth
FLAVOUR	Typical without any taints Pleasant, nutty, not too sweet
OVERALL QUALITY	Extremely good/excellent

and the score sheet was standardised. A six point Likert-type measuring scale where 6 equals the most positive and 1 the least positive response was used. Evaluations were conducted in three sessions over a two week period under controlled conditions in partitioned booths. Serving of whole and halved randomly coded muffins on white plates was done according to an incomplete balanced block design, one sample per formula per session. The mouth was refreshed by rinsing with room temperature water and eating apple slices between different samples. Muffins were evaluated for appearance, texture, flavour and overall quality (Table 2).

Physical determinations

Although several physical tests were performed, it was not included in this paper because it adds nothing additional to the sensory analysis of the quality.

Chemical analyses

Proximate chemical analyses for macro-nutrients were done according to standardised AOAC methods[21] only on samples of the full-fat control and the experimental muffins with Simplesse®.

Statistical analyses

Significant differences between muffins from different formulas were analysed using one way analysis of variance (ANOVA) and Tukey's studentised range test, using the SAS® package. The relationship among variables was analysed by means of Pearsons product-moment correlations.

Results and discussion

Sensory analysis

The identity of the control muffin was not revealed to panelists so that all the muffins were evaluated on their own merit against the memory standard established during the training sessions. According to the results all characteristics evaluated, showed statistically significant differences ($p < 0.001$) between the muffins from the different formulas. Although muffins with Simplesse® did not simulate all of the attributes of the control muffins, they were more similar to the control than the muffins with NFMS.

When comparing the muffins from the different formulas on appearance, differences are clearly visible as shown in Figures 2 and 3. According to the results in Table 3 the muffins of Formula COS (80 % oil replacement with Simplesse®) were scored significantly higher, more

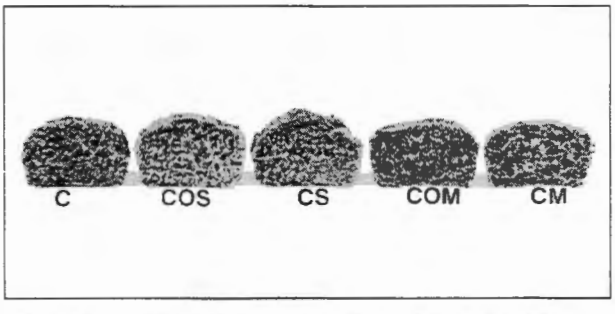

FIGURE 2: Photographs showing the crust shape and crumb structure of sliced muffins prepared according to the five formulas: C= full-fat control; COS & CS = 80% and 100% oil replacement with Simplesse®, respectively; COM & CM = 80% and 100% oil replacement with non-fat milk solids (NFMS), respectively

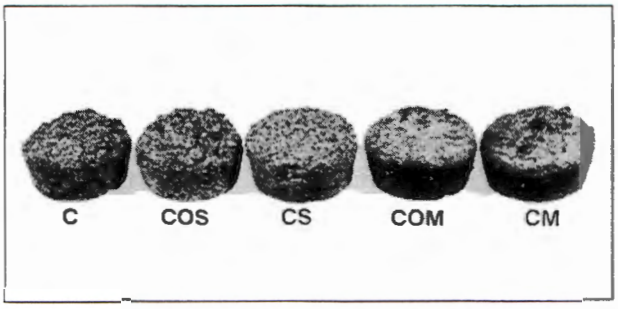

FIGURE 3: Photographs showing the appearance of whole muffins prepared according to the five formulas: C= full-fat control; COS & CS = 80% and 100% oil replacement with Simplesse®, respectively; COM & CM = 80% and 100% oil replacement with non-fat milk solids (NFMS), respectively

favourable for having a more symmetrical, even, well risen, slightly rounded crust shape, a slightly glossy, rich, dark golden brown crust colour and a more pebbled coarse crust surface compared to the less rounded, rather dull, darker brown, too coarse full-fat control muffins. Muffins of Formula CS (100 % oil replacement with Simplesse®), were scored significantly higher on crust gloss but did not differ significantly from the full-fat control on crust shape, colour or surface. No significant differences were observed between the control and experimental muffins with Simplesse® showing a dark golden brown crumb colour. The appearance of the muffins where oil was replaced by NFMS differed significantly from the control and experimental muffins with Simplesse®. They were inferior having either almost flat top crust shapes or uneven off-centred peaks, odd, very glossy yellow-brown crust colour and very smooth crust surfaces.

Comparing the texture of the sliced muffins (Table 3 and Figure 3) it is evident that the muffins with Simplesse® (COS & CS) did not differ significantly from the full-fat control on cell distribution or cell size. This corresponds with the findings of Armbrister and Setser (1994)[15] on cookies with 50 % fat replacement with Simplesse®. The texture of the muffins with NFMS (Formulas COM & CM), however, was coarse and uneven, with tunnels. The muffins of Formula COS did not differ significantly from the full-fat control on crust toughness and adhesiveness, both being not tough or sticky. The full-fat control muffins, however, were scored significantly higher for being less cohesive and more tender and compressible than both formulas with Simplesse®, although the latter were both still very tender and easy to compress in comparison to the muffins with NFMS (COM & CM). According to Love (1992)[9] fat absorbed on surfaces of gluten protein, interferes with hydration and with the development of a firm cohesive gluten structure, thus promoting tenderness in the full-fat control muffins. Fulton and Hogbin (1993)[16] also found decreased tenderness of muffins as fat levels decreased. The panelists evaluated the texture of the muffins with NFMS significantly less tender, more adhesive, cloggy at initial bite as well as after chewing and with very tough crusts compared to the control and the muffins with Simplesse®. These results correspond with the statement of Armbrister and Setser (1994)[15] that the textural attributes provided by fat in baked products, in particular, are difficult to achieve with fat replacers. They also reported significantly higher scores for cohesiveness and residual mouth coating of cookies with Simplesse® than the full-fat control but no differences in molar packing (adhesiveness).

TABLE 3: Mean (±SD) values for the sensory quality characteristics of high-fibre muffins from five formulas

Sensory characteristics#	FORMULA C 100% oil	FORMULA COS 20% oil + Simplesse	FORMULA CS Simplesse only	FORMULA COM 20% oil + NFMS	FORMULA CM NFMS only
Top crust shape	$5.25^{b} \pm 0.61$	$5.92^{a} \pm 0.28$	$5.54^{ab} \pm 0.59$	$4.13^{c} \pm 0.54$	$3.50^{d} \pm 0.66$
Crust gloss	$4.79^{b} \pm 0.51$	$5.88^{a} \pm 0.34$	$5.58^{a} \pm 0.58$	$3.92^{c} \pm 0.58$	$3.79^{c} \pm 0.66$
Crust colour	$4.88^{b} \pm 0.54$	$5.88^{a} \pm 0.34$	$5.00^{b} \pm 0.42$	$4.13^{c} \pm 0.54$	$3.83^{c} \pm 0.56$
Crust surface	$5.42^{b} \pm 0.58$	$5.88^{a} \pm 0.34$	$5.25^{b} \pm 0.53$	$3.88^{c} \pm 0.45$	$3.42^{d} \pm 0.58$
Crumb colour	$5.21^{ab} \pm 0.66$	$5.54^{a} \pm 0.51$	$5.00^{b} \pm 0.51$	$4.33^{c} \pm 0.48$	$4.00^{c} \pm 0.51$
Cell distribution	$5.46^{ab} \pm 0.51$	$5.58^{a} \pm 0.50$	$5.08^{b} \pm 0.41$	$4.04^{c} \pm 0.55$	$3.58^{d} \pm 0.65$
Cell size	$5.29^{a} \pm 0.55$	$5.42^{a} \pm 0.50$	$5.08^{a} \pm 0.58$	$4.17^{b} \pm 0.38$	$3.75^{b} \pm 0.61$
Compressibility	$5.88^{a} \pm 0.34$	$5.08^{b} \pm 0.28$	$4.75^{b} \pm 0.61$	$3.96^{c} \pm 0.36$	$3.38^{d} \pm 0.65$
Crust toughness	$6.00^{a} \pm 0.00$	$5.75^{a} \pm 0.44$	$5.00^{b} \pm 0.51$	$3.83^{c} \pm 0.38$	$2.83^{d} \pm 0.82$
Cohesiveness (initial bite)	$5.92^{a} \pm 0.28$	$5.38^{b} \pm 0.49$	$4.83^{c} \pm 0.48$	$4.00^{d} \pm 0.51$	$3.42^{e} \pm 0.72$
Cohesiveness (after chewing)	$5.79^{a} \pm 0.41$	$5.21^{b} \pm 0.51$	$4.79^{b} \pm 0.41$	$3.67^{c} \pm 0.76$	$3.17^{c} \pm 0.92$
Tenderness	$5.92^{a} \pm 0.28$	$5.21^{b} \pm 0.41$	$4.79^{c} \pm 0.51$	$3.88^{d} \pm 0.54$	$3.25^{e} \pm 0.68$
Adhesiveness	$5.75^{a} \pm 0.44$	$5.33^{a} \pm 0.48$	$4.71^{b} \pm 0.62$	$3.75^{c} \pm 0.61$	$3.38^{c} \pm 0.65$
Flavour	$5.42^{a} \pm 0.58$	$5.54^{a} \pm 0.51$	$4.83^{b} \pm 0.64$	$4.17^{c} \pm 0.48$	$3.63^{d} \pm 0.49$
Overall quality	$5.13^{b} \pm 0.34$	$5.71^{a} \pm 0.46$	$4.92^{b} \pm 0.41$	$4.13^{c} \pm 0.45$	$3.54^{d} \pm 0.59$

NFMS – non fat milk solids
Formula C – control with 100% oil
Formula COS – 20% oil + Simplesse® (80% replacement)
Formula CS – no oil, only Simplesse® (100% replacement)
Formula COM – 20% OIL + NFMS (80% replacement)
Formula CM – NFMS only (100% replacement)
Sensory scale – 1 = least positive response
6 = most positive response
abcde – means in the same row with different superscripts differ significantly ($p<0.001$)
– Each mean is the average of scores obtained from three replications, eight samples per replication

TABLE 4: Proximate chemical analysis of high-fibre muffins with different levels of Simplesse® (g/100g)

	FORMULA C 100% oil	FORMULA COS 20% oil + Simplesse®	FORMULA CS Simplesse® only
Moisture	36.37^{c}	40.27^{b}	41.14^{a}
Fat	12.72^{a}	4.07^{b}	1.58^{c}
Ash	1.91^{b}	2.25^{a}	2.32^{a}
Protein (N x 6.25)	6.90^{c}	9.35^{b}	10.39^{a}

a,b,c, Mean values in the same row with different superscripts differ significantly ($p < 0.005$)

The flavour of the muffins with 80 % replacement of oil by Simplesse® (COS) did not differ significantly from the full-fat control but was scored significantly higher than all the other formulas. The panelists described the flavour of the control and COS muffins as typical, pleasant, nutty and slightly sweet. The muffins of Formula CS were significantly sweeter while those with NFMS were sweeter, not typical, with a strange milky taint.

On overall quality the COS muffins were scored significantly higher than the control and other experimental muffins while the muffins of Formula CS did not differ from the control, all being described as excellent. This implies that oil could be replaced by Simplesse® without adversely affecting the overall quality of high-fibre muffins. In contrast the overall quality of muffins with NFMS were scored significantly lower than the control and muffins with Simplesse®. Significant ($p = 0.001$) positive correlations of 0.8471 to 0.9789 were found between overall quality and all the sensory attributes, which indicates that the sensory panel considered all the sensory attributes when they evaluated the overall quality.

Proximate chemical analyses

Proximate analyses were done only on the full-fat control and the muffins with different levels of Simplesse®. The moisture content of the muffins with Simplesse® was significantly higher than those of the full-fat control muffins with increased levels of moisture as levels of Simplesse® increased. The significantly higher protein levels as the levels of Simplesse® increased, might be the reason for the higher moisture content and could explain why the muffins with Simplesse® were more cohesive and slightly cloggy compared to the full-fat control. The fat content of the muffins with Simplesse® was significantly reduced by as much as 68 % and 84 %, respectively, by replacing oil at 80 % (COS) and 100 % (CS) levels.

No significant difference was found between the mineral content (ash) of the COS and CS samples with Simplesse® although they differed significantly from the full-fat control.

Nutritional advantage

The main nutritional advantage of fat substitution with Simplesse® is a considerable reduction in fat while the fibre content remains high. The full-fat control muffin (60 g) provides 4.5 g fibre which equals 20 % of total daily intake and 7.9 g fat representing 12.5 % fat allowance on an 8 000 kJ diet. With 80 % oil replacement each muffin contains only 2.5 g fat while with 100 % oil replacement it

contains only 1.3 g fat, representing fat reductions of 68 % and 84 %, respectively, and providing only 2-4 % of the recommended fat compared to 12.5 % fat supplied by the full-fat control. Both products with Simplesse® qualify for the low-fat claim having less than 3 g fat/serving unit.

Conclusion

The results indicated that the muffins with 80% replacement of oil with Simplesse® (COS) were scored higher than or similar to the full-fat control on all attributes except for some of the textural attributes. Although the muffins with Simplesse® only (CS) differed significantly from the full-fat control on texture and flavour, their scores still indicated high quality. The muffins with NFMS were, however, scored significantly lower on all attributes and were found to be inferior in quality. This study demonstrated that Simplesse® Dry 100 can successfully replace fat up to 100 % in high-fibre muffins without serious adverse effects on quality. It further demonstrated that non-fat milk solids (NFMS) cannot replace fat in high-fibre muffins as successfully as Simplesse®. With the current recommendations for reduction of fat and increasing of fibre in the diet, this study proved that the development of a high quality high-fibre low-fat food product with good eating qualities is possible by using Simplesse® Dry 100.

Further studies on the relationship among batter age, shelf life and perceived sensory characteristics of high-fibre muffins with Simplesse® are needed because such information could be of importance for application in hospitals or clinics. Additional work is also recommended to explore consumer acceptability of the fat-reduced muffins with Simplesse®. Differences from the control do not automatically imply that the muffins would be less acceptable to consumers.

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CHAPTER 3

DIETITIANS' ATTITUDE TOWARDS FAT SUBSTITUTES AND THE ACCEPTABILITY OF HIGH-FIBRE MUFFINS CONTAINING SIMPLESSE®

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Dietitians' attitude towards fat substitutes and the acceptability of high-fibre muffins containing Simplesse®

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Abstract

The dietary need for acceptable high-fibre low-fat food products requires that dietitians should be informed about the potential of fat substitutes such as Simplesse®. Since attitude directs behaviour to a great extent, knowledge of the attitude of South African dietitians towards the need for and dietary advantages of fat substitutes was important. The study investigated sensory acceptability and consumption intent of high-fibre muffins with zero (full-fat control), 80 % and 100 % oil replacement with Simplesse®, using a questionnaire regarding demographics, knowledge of fat substitutes, acceptability of the muffins and an attitude scale on problematic aspects of reducing fat in the diet, advantages of and need for fat substitutes. The demographics indicated that none of the dietitians fasted or avoided starches in order tc lose weight. The few that followed reducing diets consumed smaller portions or avoided fat. Almost all respondents regularly consumed energy-reduced foods, especially low-fat food products. Sensory evaluation showed that the high-fibre, low-fat muffins with Simplesse® were highly acceptable. The dietitians did not prefer the full-fat control to the experimental muffins and revealed a very positive attitude towards all the muffin variations by declaring their intention of eating them once a week. The attitude of the South African dietitians towards fat substitutes indicated that they were convinced of the advantages of and the need for fat substitutes such as Simplesse®, which could possibly predict a positive behavioural intention towards the product.

Key words: Attitude, fat substitutes, Simplesse®, acceptability, muffins

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Opsomming

Die behoefte aan aanvaarbare hoë-vesel lae-vet voedselprodukte vereis dat dieetkundiges oor die potensiaal van vetvervangers soos byvoorbeeld Simplesse® ingelig moet word. Aangesien houding gedrag tot 'n groot mate rig, is kennis aangaande die houding van Suid-Afrikaanse dieetkundiges teenoor vetvervangers en teenoor die behoefte aan en voordele daarvan belangrik. Die sintuiglike aanvaarbaarheid en voornemens ten opsigte van die eet van hoë-vesel muffins met geen (volvetkontrole), 80 % en 100 % olievervanging met Simplesse® is bepaal. Die studie het 'n vraelys insluitend demografiese inligting, kennis van vetvervangers, aanvaarbaarheid van die muffins, en 'n houdingskaal ten opsigte van vetbeperking in die dieet, voordele van en behoefte aan vetvervangers behels. Volgens die demografiese gegewens het geen van die dieetkundiges gevas of stysel vermy ten einde gewig te verloor nie. Dié paar wat wel 'n verslankingsdieet gevolg het, het kleiner porsies geëet of vet vermy. Byna al die respondente het gereeld energie-verminderde voedsel, veral lae-vet voedsel, genuttig. Sintuiglike evaluering het aangetoon dat die hoë-vesel, lae-vet muffins met Simplesse® hoogs aanvaarbaar was. Die dieetkundiges het nie die volvetkontrole bo dié met Simplesse® verkies nie en het 'n positiewe houding teenoor al drie die muffinvariasies openbaar deur te kenne te gee dat hulle dit eenkeer per week sal eet. Die houding van die Suid-Afrikaanse dieetkundiges teenoor vetvervangers dui daarop dat hulle oortuig is van die voordele van en behoefte aan vetvervangers soos byvoorbeeld Simplesse®, wat moontlik 'n positiewe gedrag teenoor die produk mag voorspel.

Introduction

Diets low in fibre and rich in fat have been associated with high prevalences of chronic degenerative diseases of lifestyle such as coronary heart disease, obesity and some types of cancer[1,2]. As a consequence of these and other nutritional concerns, it has been recommended that the amount of energy derived from fat in the diet should be reduced to less than 30 % and fibre-intake should be at least 20-30 g/day for healthy people[3,1].

Although consumers have become more concerned about health and the benefits of reducing fat intake and consuming additional fibre, successful modification of their diet remains difficult. When adopting a low-fat or prudent diet, an individual must change basic food selection and preparation patterns and often limit intake of many favourite foods[4]. A dual approach is recommended, namely, nutrition education by dietitians and new food technologies to develop appealing lower-fat foods. The possibility of replacing fats in foods through the use of alternative ingredients such as fat substitutes has generated substantial interest among food scientists and nutrition professionals[5]. According to Civille[6] the use of Simplesse® as a fat substitute provides an opportunity to

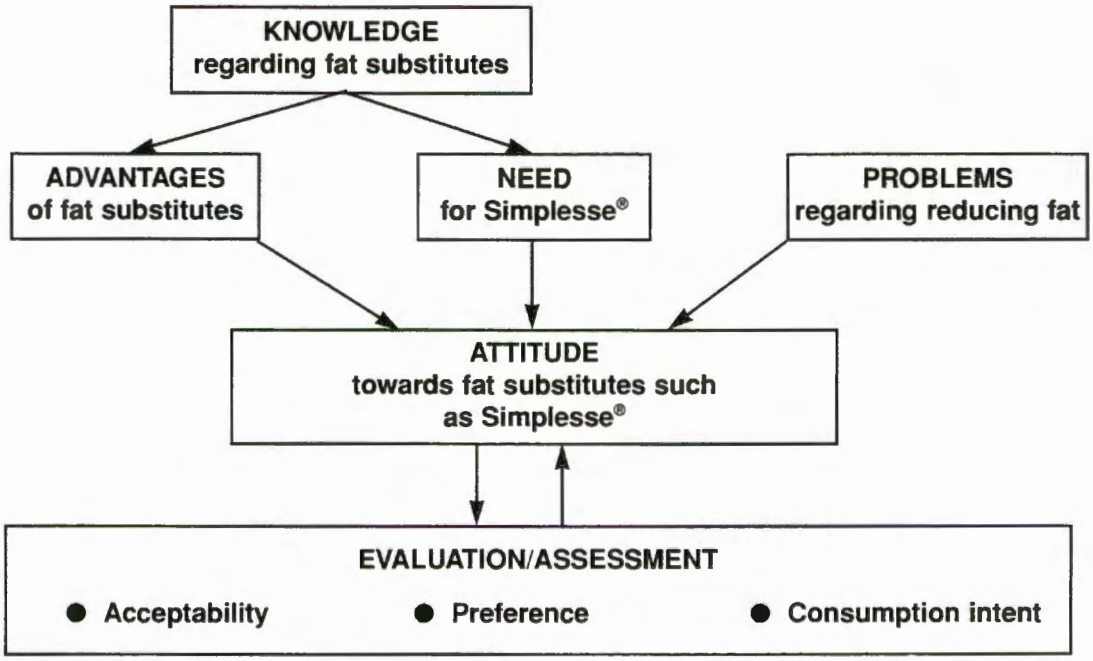

FIGURE 1: Experimental design - factors influencing attitude towards fat substitutes used in high-fibre muffins

develop healthier products, lower in fat, with little or no sensory sacrifice which means greater compliance with low-fat diets. Simplesse®, a low-energy protein-based fat substitute consisting of microparticulated milk whey and/or egg proteins, sugar, pectin and citric acid furnishes only 5,6 kJ per gram. When hydrated, each gram of Simplesse® can replace 3 gram of fat, which implies a considerable energy reduction[7]. Erdman[8] concluded that microparticulated proteins can be used safely without compromising protein quality while Corliss[9] also reported on the safety of Simplesse®. Bosman et al.[10] demonstrated, by using a descriptive sensory panel, that Simplesse® Dry 100 can successfully replace oil in high-fibre muffins which are widely used by individuals who need to follow a low-fat diet.

Although Simplesse® is not yet available in South Africa, the need for acceptable low-fat food products for the prudent diet necessitates that dietitians should be informed about its potential. Since attitude has the important psychological function of directing behaviour[11], it is also necessary to determine dietitians' attitudes towards fat substitutes, as they play an important role in the modification of the eating habits of their patients and clients.

Despite descriptive sensory analysis during product development, the consumer ultimately decides on the acceptability and eventually the consumption of food[12]. It is thus essential to determine whether muffins with Simplesse® are acceptable and which sensory attributes drive acceptance. According to Baker et al.[13] acceptance could be defined as a positive attitude after the tasting experience. Without acceptable flavour, texture and appearance any product will be deemed unacceptable by the consumer[14]. Acceptability of products will influence the reaction towards their utilization and promotion by dietitians. From attribute acceptance scores one can infer total or overall acceptance, the sample with the higher mean being the most acceptable[15]. An even more important overall measure of food acceptance, beyond simple liking, is the frequency of consumption. Consumers may like a product but may not consume it frequently[12]. This action scale requires the individual to be very specific about what actions he would take in terms of the number of times he would eat the food product in a given period. No information on the attitudes of South African dietitians towards fat substitutes is available. Therefore, the objectives of this study were:

- To investigate dietitians' awareness and knowledge regarding fat substitutes such as Simplesse®
- To inform dietitians about the characteristics and application of fat substitutes such as Simplesse®
- To assess the acceptability of, preference for and consumption intent regarding high-fibre muffins containing various levels of Simplesse® using hedonic and food action rating scales
- To develop and apply an attitude scale to determine the attitude of dietitians towards

i) the problematic aspects of reducing fat in the diet

ii) advantages of fat substitutes in the diet and

iii) the need for using Simplesse®.

Methods

The experimental design for this study is given in Figure 1.

Subjects

Subjects consisted of two groups of dietitians from the Association for Dietetics in Southern Africa, namely 50 members from the Pretoria branch (Group 1) and 51 members from the Gauteng South branch (Group 2) of which all but three were female. Fifty eight were between 21 and 30 years of age, twenty seven between 31 and 40 and sixteen were older. Forty four of the respondents completed their studies after 1990 and only ten before 1970. Nearly half (49) were clinical dietitians.

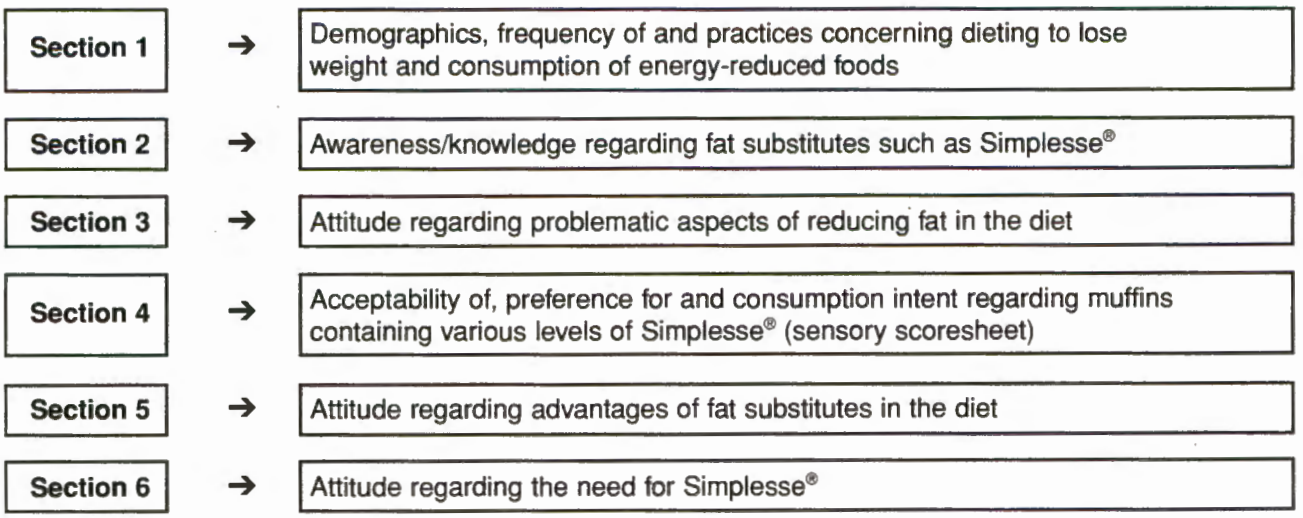

FIGURE 2. Structure of the questionnaire utilised for data collection

Questionnaire

The questionnaire consisted of six sections (Figure 2). For practical reasons, the study was conducted in two phases. After group 1 had completed the questionnaire, the results were surveyed and it was decided to add a few more questions at each of sections 1, 2, 5 and 6 to obtain additional information. Group 2 completed the extended questionnaire. The seven-page questionnaire required approximately 15 min to complete with an additional 15 min to access the acceptability of the muffins. In section 1, all subjects (101) completed the questions on demographics and only group 2 (51) the other 4 questions. Section 2 consisted of 8 questions of which all but one, were completed by all the subjects. All 10 statements in section 3 as well as section 4 (sensory scoresheet) were completed by both groups. In section 5, nine statements were completed by group 1 and one statement was added for group 2. Section 6 contained 8 statements which were completed by group 1, while two more statements were added for completion by group 2. The attitude statements and scale (sections 3, 5 and 6) are given in Appendix 1. The responses on the categories used in the attitude scale (1-5, where 1 = strongly agree and 5 = strongly disagree) were computed as follows: for positive statements, 1 = 5 points, 2 = 4 points, 3 = 3 points, 4 = 2 points and 5 = 1 point. For negative statements, the counts were reversed (1 = 1 point, 5 = 5 points).

Validity and reliability of the attitude scale

For this attitude scale consisting of three subscales, each question or statement was considered an individual measure of an attitude according to the recommendations of Henerson *et al.*[16]. Validity and reliability were determined in order to assess whether the instrument measures what it needs to measure and whether it yields consistent results, respectively.

Validity

According to Henerson *et al.*[16] validity can be viewed as the extent to which alternative interpretations of the instrument's results can be ruled out. Construct validity refers to the extent to which you can be sure the instrument represents the construct of which the name appears in its title.

Construct validity for this study was assessed by means of confirmatory factor analysis, as described by Van Aardt and Steyn[11]. Each of the subscales was subjected to a factor analysis, using principal components for factor extraction. The FACTOR procedure of SAS was used for this analysis. According to Smith *et al.*[17], a scale displays good construct validity when one (the ideal) or only a few factors are extracted, which together explain a substantial proportion of the variance, and when high communalities are obtained for each statement.

Results of validity determination

The number of factors extracted, the percentage of total variance explained by these extracted factors and the range of communalities on the factors for each attitude subscale are given in Table 1. Since some of the subscales had one or two more statements for group 2, the results of those subscales (sections 5 and 6) are given separately for group 1 and 2. One subscale (section 3) did not differ for the two groups.

Only a few factors (maximum 4) were extracted for all the subscales, and a substantial proportion of the variance was explained by these factors in all cases. The communality on each statement contributed more than half of the total variance for most of the statements. In section 3, both groups had one, and in section 6 both groups had two statements with communalities < 0.5. Group 1 in section 5 had three statements with communalities < 0.5, while for Group 2, section 5, all statements had communalities > 0.6. When comparing these results with the criteria for a valid scale as described by Smith *et al.*[17], it can be assumed that all the subscales have a satisfactory validity.

Reliability

A reliable attitude scale displays internal consistency, which refers to the tendency of the different items on the scale to elicit the same attitude from any given respondent on a single administration of the test[16]. Test reliability can be determined in many ways. According to Anastasi[18], Cronbach's alpha coefficient is a suitable

TABLE 1: Factors extracted, total variance explained and the communalities on the statements for the various attitude subscales for group 1 and 2

Section*	Number of factors extracted	Total variance explained (%)	Range of communalities
3 - group 1	4	65.29	0.44 - 0.85
3 - group 2	4	66.94	0.48 - 0.75
5 - group 1	3	55.83	0.27 - 0.75
5 - group 2	4	70.53	0.55 - 0.86
6 - group 1	3	66.46	0.38 - 0.85
6 - group 2	3	65.14	0.31 - 0.80

* Section 3: Attitude towards the problematic aspects of reducing fat in the diet
Section 5: Attitude towards advantages of fat substitutes in the diet
Section 6: Attitude towards the need for using Simplesse®

measure for tests with multiple-scored items which are administered once, as was used in this study. The procedure comprises the determination of the variance of all individuals' scores for each item and the addition of these variances across all items.

Results of reliability determination

The Cronbach α-coefficients for the various attitude subscales are given in Table 2. From Table 2 it is clear that the reliability coefficients for sections 5 and 6 are quite high, while for section 3 it is on the low side, although still acceptable. Consequently, it can be concluded that this attitude scale displays a satisfactory reliability.

Samples for assessment of acceptability

Three batches of high-fibre muffins with various levels of Simplesse® were freshly mixed and baked as described by Bosman *et al.*[10]. After being cooled for two hours each sample was vertically divided in half. A three digit number code was allocated to each batch, namely 305 to the full-fat control, 510 to the muffins with 80 % oil replacement and 978 to the muffins with 100 % oil replacement with Simplesse®. Rectangular styrofoam containers were labeled with the three sample codes according to an incomplete balanced block design. Three muffins, one from each batch, with corresponding codes were subsequently placed onto the containers, cut side down, and sealed in a plastic bag. Samples were presented in balanced order to ensure that every possible order occurred an equal number of times. Two evaluation sessions of 15 min each were conducted under controlled conditions in conference rooms. On arrival, subjects were welcomed, seated and presented with a numbered series of samples and a questionnaire. Since the survey was conducted prior to the introduction of products containing Simplesse® in South Africa, a brief explanation of the composition, characteristics and use of Simplesse® was given after completion of sections 1 to 3, prior to the sensory evaluation of the muffins and completion of sections 5 and 6. Brief instructions on the use of the sensory scoresheet were also given.

Sensory tests

Three sensory tests, namely the hedonic rating of the acceptability of each sensory attribute, a preference test and a food action rating test were conducted in sequence. Subjects rinsed with water before and between tasting the samples. In the first test, subjects were asked to rate the degree of acceptance of each muffin variation with regard to overall appearance, colour, texture and flavour on a 5-point hedonic scale (1 = extremely unacceptable; 5 = extremely acceptable). Overall acceptance was calculated from the attribute acceptance scores. Secondly, the subjects were asked whether they preferred one specific muffin to the others and if so, which one. Consumption intent was determined by using a 5-point food action or attitude scale, with response categories ranging from "eating it everyday" (5) to "never eating it" (1). Upon completion of the tests, the experimenter checked the scoresheet of each subject for completeness.

Statistical analyses

Demographic data, data on practices concerning dieting to lose weight, consumption of energy-reduced foods, awareness and knowledge regarding fat substitutes were analysed using descriptive statistics. Analysis of vari-

TABLE 2: Cronbach's α-coefficients for sections 3, 5 and 6 for group 1 and group 2

Section *	α (Group 1)	α (Group 2)
3	0.446	0.421
5	0.522	0.651
6	0.713	0.761

* Section 3: Attitude towards the problematic aspects of reducing fat in the diet
Section 5: Attitude towards advantages of fat substitutes in the diet
Section 6: Attitude towards the need for using Simplesse®

ance (ANOVA) was applied to the hedonic attribute scores and food action ratings for each of the muffin variations using the SAS® package. A Tukey's multiple comparison test ($p \leq 0.05$) was performed on the means when significant differences were found in the ANOVA. Stepwise discriminant analyses were done to determine which sensory attributes drive acceptance and preference. Chi-square tests and multiple comparison of the proportion of preference were performed to determine which of the muffin variations was preferred[19]. Validity was investigated by means of factor analysis for sections 3, 5 and 6 while reliability was assessed by determining Cronbach's α coefficients.

Results

Frequency of and practices concerning dieting to lose weight

Results of section 1 gives an indication of practices of dietitians regarding dieting to lose weight and consumption of energy-reduced foods (Table 3). More than half (57 %) of the dietitians never or rarely dieted while only 16 % often or always dieted to lose weight. Two thirds consumed smaller portions, one third avoided fat while only 10 % avoided sugar to lose weight. Fasting, skipping meals and avoiding starches were not practiced. Only 8 % exercised with the specific aim of losing weight.

Almost all the dietitians reported regular consumption of one or more of the energy-reduced foods mentioned in Table 3. Low-fat products were most frequently (59 %) consumed, while nearly half consumed low-fat dairy products and diet beverages. About a third consumed sugar-free and fat-free products.

Awareness and knowledge regarding fat substitutes

Analyses of awareness and knowledge data with respect to fat substitutes showed that 79 % of the dietitians knew about fat substitutes in general. A group of 58 % was aware of research on the physiological effects of Simplesse®, while 56 % were aware of research regarding fat substitutes in product development.

The knowledge test revealed that 91 % of the dietitians knew that Simplesse® is safe to use, 80 % knew that fat substitutes reduce the energy content of foods, 72 % knew that fat replacements in products have more advantages than eating smaller portions of high-fat products, while only 49 % knew how Simplesse® is manufactured.

Attitudes towards problems concerning reducing fat, advantages of and the need for fat substitutes in the diet

Attitudes towards various aspects of fat substitutes were tested in sections 3, 5 and 6. The mean attitude scores for all items in each section which were similar for both groups are reported for the total group in Table 4 while the mean scores for the supplemental statements, completed by group 2 only, are reported separately.

According to the data presented in Table 4, problems with respect to reducing fat in the diet ($\bar{X} = 3.04$) did not seem very prominent to dietitians as they revealed a fairly neutral attitude towards the issue. With respect to the advantages of fat substitutes, however, a highly positive

TABLE 3: Frequency and methods of dieting to lose weight and regular consumption of various energy-reduced foods (n=51; group 2)

Frequency	%	Methods	%	Energy-reduced foods consumed regularly	%
Never	22	Fast	0	Diet beverages	47
Rarely	35	Skip meals	2	Low-fat dairy	49
Sometimes	27	Avoid starches	0	Sugar-free products	37
Often	14	Avoid sugars	10	Fat-free products	31
Always	2	Avoid fats	33	Low-fat products	59
		Eat smaller portions	67		
		Exercise	8		

TABLE 4: Mean attitude scores# regarding problems with respect to reducing fat in the diet, advantages of and the need for fat substitutes such as Simplesse® (N=101)

Section		Mean score
3	Problems with respect to reducing fat in the diet[1]	3.04
5	Advantages of fat substitutes[2]	4.20
6	Need for Simplesse®[3]	4.12

\# 1 - highly negative attitude, 5 = highly positive attitude

[1] high score indicates high problem count

[2] high score indicates great advantages of fat substitutes

[3] high score indicates a great need for Simplesse®

attitude ($\bar{X}$ = 4.20) was encountered for section 5. The mean score of 4.12 for the supplemental statement which tested whether group 2 was of the opinion that the availability of low-fat foods, containing fat substitutes, will increase the variety of food for the prudent diet, also indicated a highly positive attitude regarding the advantages of fat substitutes. In accordance with these results, a great need for Simplesse® was indicated by the mean score of 4.12 for section 6.

Supplemental statements 9 and 10 (section 6) which tested whether a low-fat diet is currently the healthy trend and whether diet is important in avoiding health problems such as heart disease and cancer, also indicated a highly positive attitude ($\bar{X}$ = 4.56) towards the need for low-fat diets.

Acceptance, preference and frequency of consumption

The results of the hedonic and food action tests are shown in Table 5. Hedonic sensory data showed no significant differences ($p \leq 0.05$) in terms of acceptance between the full-fat control muffins and the experimental muffins with Simplesse®. The high scores obtained (means between 3.79 and 4.28 on a five point scale), indicated high acceptance of all the muffin variations in terms of the individual attributes namely appearance, colour, texture and flavour as well as overall acceptance. The latter was calculated as the mean of all the attribute acceptance scores. Although muffins with 80 % replacement of oil were statistically more acceptable in total and on colour and flavour than the muffins with 100 % replacement of oil with Simplesse®, the latter was still highly acceptable.

No significant differences in preference were obtained for any of the different muffin variations and stepwise discriminant analysis revealed texture to be the most important sensory attribute that drives preference. This is in accordance with Stone *et al.*[20] who also reported that the texture of baked products appears to be more important to consumers than the flavour.

The full-fat control and the muffins with Simplesse® also did not differ significantly on frequency of consumption as an overall measure of acceptance. The dietitians revealed a very positive attitude towards all the muffin variations by declaring their intention of eating them once a week. Flavour seemed to be the sensory attribute that best explained the consumption intent regarding all the muffin variations.

Discussion

More than half of the dietitians who took part in this study were younger than 31 years, reflecting the current training status of the profession. In accordance with sound eating practices as summarised by Mahan and Arlin[21], no dietitians fasted or avoided starches in order to lose weight. Studies conducted in the United States (US)[22], Australia[23], as well as in South Africa[24], showed that 34.9 %, 14.5 % and 16.8 % respectively of women who were not specifically educated in nutrition, fasted while 21 % in another US study[25] skipped meals to lose weight. Very few of the respondents often dieted, and the few that did, mostly consumed smaller portions or avoided fat. They did, however, regularly consume energy-reduced foods such as low-fat products, low-fat dairy products and diet beverages, which indicates an awareness of the importance of these items in order to control weight. These findings are consistent with the observations of Levy and Heaton[25] regarding weight reduction practices in the US. This study showed that US men and women attempting to lose weight in non-clinical settings consumed low-energy soft drinks, used low-energy sweeteners and consumed low-fat dairy products. As previously reported by Drewnowski[26], fat replacements offer one strategy for energy reduction It is consequently reasonable to assume that the low-fat, high-fibre muffins in which oil is replaced by Simplesse®, will be a popular dietary product among dietitians. Although fat

TABLE 5: Mean (±SD) scores for the acceptance of attributes and consumption intent of high-fibre muffins from three formulas evaluated using five-point hedonic and food action rating scales (N = 101)

Attribute	Formulas		
	Formula 1 (control 100 % oil)	Formula 2 (20 % oil & Simplesse®)	Formula 3 (only Simplesse®)
● Acceptance*			
Appearance	4.05[a] ± 0,88	4.28[a] ± 0.59	4.05[a] ± 0.73
Colour	4.09[ab] ± 0.86	4.31[a] ± 0.61	3.96[b] ± 0.82
Texture	3.87[a] ± 0.92	3,98[a] ± 0.72	3.79[a] ± 0.79
Flavour	4.02[ab] ± 0.93	4.16[a] ± 0.63	3.87[b] ± 0.81
Overall acceptability	4.02[ab] ± 0.71	4.18[a] ± 0.50	3.94[b] ± 0.50
● Consumption intent#	3.84[a] ± 0.96	3.98[a] ± 0.79	3.84[a] ± 0.87

[ab] Means with different superscripts in a row, differ significantly ($p < 0.05$)

* 1 = Extremely unacceptable 5 = Extremely acceptable

\# 1 = will never eat it 5 = will eat it everyday

N = number of assessors

substitutes are not yet readily available in South Africa and Simplesse® not at all, dietitians seem to be well aware of research on these products and their safety. The dietitians were also knowledgeable regarding the dietary advantages as stated by various authors[21,27,28].

Despite nutritional advantages of a product it has been emphasized[12,13] that a food product will not be a success unless its sensory attributes are acceptable to the consumer. This study indicated that high-fibre, low-fat muffins prepared with Simplesse® were extremely acceptable to the respondents, who did not prefer the full-fat control to the experimental muffins. In accordance with Stone *et al.*[20] texture seemed to be the most important sensory attribute that drives preference in baked products. The dietitians also expressed an intention of regularly eating the product. These findings might reflect their positive attitude towards muffins with Simplesse®, as Shephard and Stockley[29] concluded that a person's attitude towards eating a specific food proved to be a better predictor of behavioural intention than general attitudes.

Regarding the attitude of dietitians towards fat substitutes, the results reflect that although dietitians do not seem to have serious problems with fat limitation in the treatment of their patients, they are convinced of the advantages of fat substitutes such as Simplesse®, among other in providing a greater variety of low-fat foods. That there is a great need for fat substitutes, especially in the light of the important role which diet plays in prevention of chronic diseases, cannot be doubted.

It can be concluded that South African dietitians generally practice healthy eating habits. They consume low-fat products, which implies that high-fibre, low-fat muffins prepared with Simplesse® will be a welcome and much needed addition to available energy-reduced foods. This product also seems to be highly sensory acceptable, which is the ultimate criterion for consumer consumption.

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APPENDIX 1: Statements included in the final attitude scale

SECTION 3: Problems with respect to reducing fat in the diet.

1. It is easy to convince patients to reduce their fat intake.
2. Patients find it difficult to follow a low-fat diet (30 % or less) over an extended period of time.
3. The lack of low-fat products makes it difficult to follow a low-fat diet.
4. Individuals are easily motivated to lose weight by limiting the fat in their diet.
5. Reducing dietary fat does not make the diet unpalatable.
6. Low-fat diets are not expensive.
7. Low-fat products are unpalatable.
8. The advantageous effect of low-fat products will be cancelled by the fact that people will then eat more of the product.
9. Members of the general public are willing to use low-fat products.
10. Few low-fat products are commercially available.

SECTION 5: Advantages of fat substitutes

1. The use of products containing *Simplesse* is not beneficial to one's health.
2. I will use products containing *Simplesse* in fat-limited diets.
3. Excessive fat intake is not detrimental to one's health.
4. An advantage of *Simplesse* is that it only substitutes the fat in the product and does not change the macro-nutrient composition significantly.
5. There is no need for fat substitutes to replace fat in the diet.
6. The general public will not use food products which contain fat substitutes.
7. I favour *Simplesse* because it is not a synthetic product.
8. *Simplesse* can be used as a beneficial contribution to the control of diabetes mellitus.
9. If available, I will recommend the use of products containing *Simplesse*.
10. The availability of low-fat products containing fat substitutes will increase the variety of food for selection in the prudent diet.

SECTION 6: Need for fat substitutes such as Simplesse

1. Fat substitutes such as Simplesse should be used in food products where fat limitation in the diet is needed.
2. Fat limitation of up to 30 % or less of the total energy intake of the diet is facilitated by using fat substitutes.
3. *Simplesse* reduces the general acceptability of products.
4. The use of fat substitutes in food products does not provide exceptional advantages.
5. Fat substitutes do not contribute to a tasty low-fat diet.
6. Products containing *Simplesse* can be used successfully in slimming diets.
7. The use of *Simplesse* does not offer advantages for a prudent diet.
8. The availability of ice cream containing *Simplesse* facilitates the planning of low-fat diets.
9. A diet low in fat (30 % or less) is the healthy trend of today.
10. Diet is important in avoiding problems such as heart disease/cancer.

CHAPTER 4

CONSUMER ACCEPTANCE OF HIGH-FIBRE MUFFINS CONTAINING SIMPLESSE®

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CONSUMER ACCEPTANCE OF HIGH-FIBRE MUFFINS CONTAINING SIMPLESSE ®

Magdalena JC Bosman, Hester H Vorster, A Drewnowski & HS Steyn

OPSOMMING

Aanduidings dat Suid-Afrikaners nie aan die vereistes vir vet- en veselinname van die omsigtige dieet voldoen nie, noodsaak die ontwikkeling van aanvaarbare hoëvesel-laevet- voedselprodukte. Ten spyte daarvan dat met behulp van beskrywende sintuiglike analise bevind is dat Simplesse® Dry 100 olie in hoëveselmuffins kan vervang, is dit uiteindelik die verbruiker wat oor die aanvaarbaarheid en verbruik van die voedsel besluit. Die sintuiglike aanvaarbaarheid van, voorkeur vir en voornemens ten opsigte van die eet van hoëveselmuffins met geen (volvetkontrole), 80% en 100% olievervanging met Simplesse® is deur 172 verbruikers met behulp van hedoniese beoordelingskale en skattingskale vir voorkeur en aksie bepaal.

Volgens die dieetverwante gegewens het die meeste verbruikers gesonde eetgewoontes gehad, hulself nie as oorgewig beskou nie en ook selde of ooit verslankingsdiëte gevolg. Baie min het gevas, stysel vermy of etes oorgeslaan ten einde gewig te verloor. Dié wat wel wou verslank, het kleiner porsies geëet of hulle vetinname verminder. Meer as 50% het gereeld energieverminderde voedsel, veral laevetvoedsel, genuttig. Ten spyte daarvan dat die verbruikers die volvetkontrole-muffins verkies het en dit meer aanvaarbaar gevind het, ten opsigte van die tekstuur as die eksperimentele muffins waar 80% van die olie deur Simplesse® vervang is, was dié met Simplesse® nog hoogs aanvaarbaar ten opsigte van al die eienskappe. Die verbruikers het ook 'n besonder positiewe houding teenoor al die muffinvariasies geopenbaar en was van voorneme om die kontrole-muffins en dié waarvan 80% van die olie vervang is elke dag te eet, en dié waarvan 100% van die olie deur Simplesse® vervang is een maal per week te eet. Dit is dus duidelik dat Simplesse® met sukses as vetvervanger in hoëveselmuffins gebruik kan word om 'n hoogs aanvaarbare laevet-hoëvesel-produk te ontwikkel wat gesondheidsbewuste verbruikers bereid is om dikwels te eet. Veranderlikes ten opsigte van gewigsbeheer (met die uitsondering van die gebruik van suikervrye produkte en die vermyding van suiker) blyk nie die aanvaarbaarheid van die muffins of die voorneme om die muffins te eet, te beïnvloed nie.

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INTRODUCTION

Despite recommendations to reduce their fat intake and to increase their fibre intake (Health Matters Advisory Committee, 1992) compliance with prudent guidelines by South Africans is disappointing (Vorster *et al*, 1995). Food scientists have been searching for ways to reduce the fat content of products and to provide feasible fibre carriers for increased fibre intake (Vratanina & Zabik, 1978) without influencing the acceptability of these products. However, in most foods, removing or reducing the fat content has a profound impact on the sensory characteristics and consumer preferences (Lindley, 1993; Hatchwell, 1994; Fulton & Hogbin, 1993). Baked products are of special interest because fat performs a major role in the eating and keeping quality of the product (Conforti *et al*, 1996). Although consumers want foods with less fat, they do not want to sacrifice the sensory attributes such as tenderness and flavour.

Another way to reduce the total fat content is to replace the fat in bakery products with the latest products in food technology, namely fat substitutes such as Simplesse® (Charlton & Sawyer-Morse, 1996; Conforti *et al*, 1996). Simplesse®, which consists of microparticulated milk whey proteins, furnishes only 5,6 kJ per gram when hydrated (Smith, 1993). Each gram of Simplesse® hydrated in 2 g of water can replace 3 g of fat, which implies a considerable energy reduction (Gershoff, 1995; Glueck *et al*, 1994). Bosman *et al* (1996) demonstrated by way of a descriptive sensory panel that Simplesse® Dry 100 can successfully replace oil in high-fibre muffins. Few studies, however, have evaluated the effects of these replacements on the acceptability of the sensory attributes that are believed to be important to consumers (Charlton & Sawyer-Morse, 1996). According to Baker *et al* (1994) the consumer is the key to the success of new products as it is the consumer who decides whether the food is acceptable or not.

Accepting a food is a dynamic process in which the relationship between the food and the person changes from one moment to the next, and depends on the situation in which the person consumes the food. Therefore acceptability and preference should not be analysed by assuming that either is static or context-free characteristics of either foods or people. The determinants of acceptability can be roughly categorised as the sensory characteristics of the food, the physiological state of the consumer, the sociopsychological context of consumption, and the effects of learning on all these categories (Booth 1981:64).

Sensory testing is used to determine whether consumers like a product (acceptance), whether they prefer one product to others (preference), and/or whether they intend to consume a product regularly (food action or attitude rating - FACT). These tests may appear identical. However, it is possible for a consumer to show a strong preference for a sample but not to consume it frequently or to reject it for reasons other than not liking it (Penfield & Campbell, 1990:70).

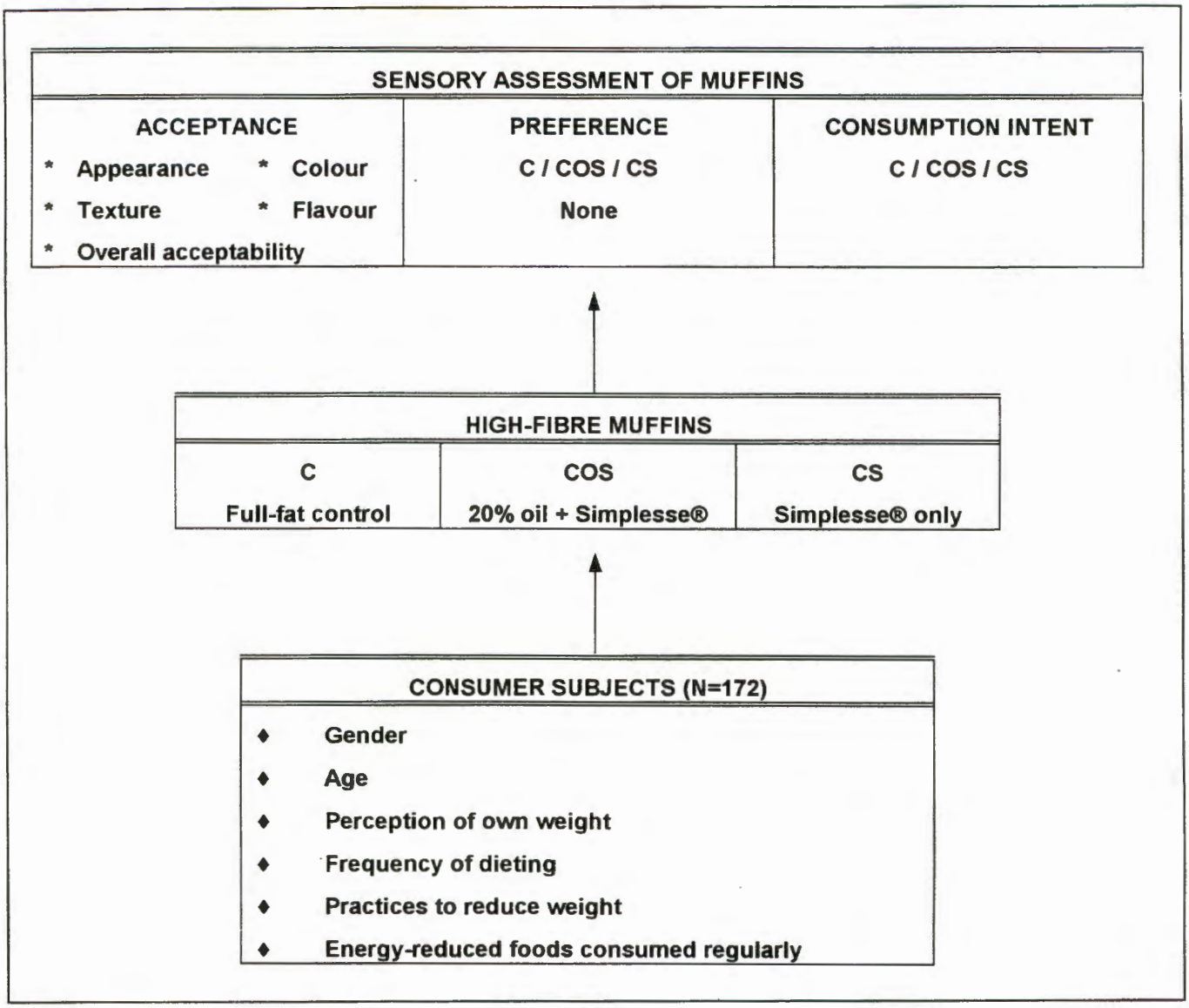

FIGURE 1: EXPERIMENTAL DESIGN

Acceptance may be defined as a positive attitude after the tasting experience and is directly measured on a hedonic scale (Baker *et al*, 1994:88). In addition to overall acceptance, acceptance of individual sensory attributes such as appearance, flavour and texture may be measured (Meilgaard *et al*, 1991:202). Acceptance measurement began as a means of predicting consumption, but it is now believed that consumption measures provide an even better index of acceptance (Meiselman *et al*, 1988:86). The food action rating test (FACT), which requires the consumer to estimate frequency of consumption of the product, is more sensitive and action-oriented than the hedonic test because consumers tend to be more realistic when they evaluate or predict actions (Penfield & Campbell, 1990:71). It is therefore important to determine whether muffins with Simplesse® will at least be equally acceptable or preferable than full-fat control muffins and whether consumers intend to consume such muffins regularly.

The objective of this study was to assess the effect of partial and total oil replacement with Simplesse® on consumer acceptance, preference and intended consumption of high-fibre muffins. A second objective was to determine which of the selected weight control variables influenced consumers' acceptance or intended consumption.

METHODS

Subjects (consumer sensory panel)

The target population was defined as actual or potential consumers of high-fibre muffins. Assuming that all consumers are capable of assessing the acceptability of food products and as this was a single blind testing event, available volunteer consumers who were including or willing to include high-fibre muffins in their diet were recruited (McWilliams, 1993:45). Posters were displayed at three large employment institutions in Potchefstroom between two and four weeks before commencement of the study. Information on the product, and the time, duration and location of the test were given. Candidates who responded by putting their names on a list were prescreened by telephone in order to control demographic factors such as gender, age and product usage, and were subsequently invited by written confirmation for a specific session. A total of 172 consumers took part in the consumer tests conducted at central locations. The experimental design for this study is presented in Figure 1.

Questionnaire

The questionnaire, consisting of two sections, was prescreened and pretested to ensure that it was well understood and that the subjects would have no difficulty in completing it within a reasonable period (± 15 min). If not understood, questions were reformulated and a few terms were described and explained to the subjects. Perception of own body weight was described as body weight according to one's opinion, belief or view. Fasting was defined as not eating any food, but drinking kilojoule-restricted liquids for alternating periods. Eating smaller portions of a balanced diet was described as eating less while including all the food groups, ie a moderate energy-restricted diet.

The many possible methods of dieting that are often vaguely defined in the literature or simply referred to as dieting without any description, cause a major problem when the results of weight-loss practices have to be compared (Grunewald, 1985). For the purpose of this study, dieting approaches such as eating smaller portions, eating less, counting kilojoules, consuming fewer kilojoules and high-energy foods were all considered to be moderate energy-restricted diets, and were assumed to be nutritionally adequate.

Section 1 of the questionnaire was designed to obtain demographic and weight control-related information on the subjects in terms of gender and age, perceptions of own weight, frequency of and practices concerning dieting to reduce weight and the kinds of energy-reduced foods the respondents consumed regularly. Section 2 was the score sheet for the sensory consumer testing.

Sample preparation and presentation

All procedures were standardised and pretested on preparation, handling and serving. Three batches of high-fibre muffins with zero (full-fat control C), 80% (COS) and 100% (CS) oil replacement with Simplesse® were freshly mixed and baked as described by Bosman *et al* (1996) before each test session. After having cooled for two hours, each sample was vertically divided in half and coded with three-digit numbers. Three muffins, one from each batch, were placed on rectangular styrofoam containers with the cut side down and sealed in a plastic bag. The samples were presented according to an incomplete balanced block experimental design in order to minimise order effects. It was ensured that each sample appeared in every position an equal number of times. Two evaluation sessions of 15 minutes each were conducted consecutively, twice per week at 10:00 and 11:00 for three weeks, under controlled conditions in conference rooms. On arrival the subjects were welcomed, seated and presented with a numbered series of coded samples and a questionnaire. A brief explanation of the composition, characteristics and use of Simplesse® as well as instructions on completing the questionnaire and the sensory score sheet was given prior to the sensory evaluation of the muffins. The subjects were supplied with water (22 °C) for mouth rinsing before and between tasting the samples. All samples were evaluated once by each subject.

Consumer sensory tests

Three sensory tests were conducted in sequence. In the first test the subjects had to taste and rate the degree of acceptance of each muffin variation independently on overall appearance, colour, texture and flavour. A 5-point hedonic scale was used (1 = extremely unacceptable; 5 = extremely acceptable). An acceptable mean was arbitrarily set at > 2,5 as the panellists were instructed that any rating at midpoint or above would be considered acceptable (Pollizoto *et al*, 1983; Azlyn *et al*, 1989). Overall acceptance was calculated from the attribute acceptance scores. The subjects were also asked to indicate whether they preferred one specific muffin to the others and if so, which one. Consumption intent was determined by using a 5-point food action rating scale, with response categories ranging from "never eating it" (0-1), to "will eat it only when no other food is available" (>1<2), "will eat it occasionally - once per month" (>2<3), "will eat it often, once per week" (>3<4) and "eating it every day" (4-5).

Statistical analyses

The data of Section 1 of the questionnaire were analysed by using descriptive statistics. Analysis of variance (ANOVA) and Tukey's multiple comparison tests ($p \leq 0,001$) were applied to the hedonic attribute scores and food action ratings for each muffin variation, using the SAS® package. Chi-square tests and multiple comparison of the proportion of preference were performed to determine which muffin variation was preferred. Stepwise discriminant analyses were done to determine which sensory attributes drive preference and consumption intent as an overall measure of acceptance. Multivariate analysis of variance (MANOVA) was applied to the demographic and weight control variables for acceptance and consumption intent of the three muffin formulas simultaneously. Significant MANOVA results were individually analysed by means of T-tests for each formula.

RESULTS AND DISCUSSION

Respondents

The gender distribution among the different age groups of the sample of 172 consumers is described in Table 1. Of this sample 51% were male and 49% were female. Nearly a third of the respondents was between 21 and 30 years of age, a third was between 31 and 40, and a third was older than 40 years. The consumer sample consisted of an even gender distribution among the different age groups, which helped in comparing the data. More than 60% of these consumers of high-fibre muffins considered themselves as having the "right body weight" and rarely or never dieted. Very few fasted, skipped meals or avoided starch in order to lose weight. They controlled their body weight by eating smaller portions and energy-reduced foods, especially diet beverages and low-fat products. A summary of the demographic characteristics and results on the weight control variables is presented in Tables 1 and 2 and Figures 2 and 3. On average the respondents seemed to be a fairly health-conscious group of consumers.

Acceptance, preference and intended consumption of muffin variations

Acceptability the muffins The results of the hedonic and food action tests are presented in Table 3. According to these results the hedonic responses to the three muffin variations varied with increased oil replacement. Although the results for acceptance indicated small and some statistically significant differences, all the muffins with Simplesse® were scored as highly acceptable on all the attributes according to the mean hedonic scores obtained (means between 3,75 and 4,28 on a five-point scale).
The muffins with 80% oil replacement by Simplesse®

TABLE 1: DESCRIPTION OF RESPONDENTS (N = 172)

	Gender			
Age	**Male**	**Female**	**Total**	**% of total**
21-30 years	31	25	56	33
31-40 years	27	27	54	31
> 40 years	30	32	62	36
Total	88	84	172	100

TABLE 2: PRACTICES TO REDUCE/CONTROL WEIGHT AND REGULAR CONSUMPTION OF VARIOUS ENERGY-REDUCED FOODS BY CONSUMERS (N = 172)

Practices to reduce/control weight	Frequency	%	Male % N = 88	Female % N = 84	Chi ^{2}-value	P-value
Fasting	3	2	2	1	0,294	0,588
Skipping meals	19	11	9	13	0,701	0,402
Avoiding starch	10	6	3	8	1,903	0,168
Avoiding sugar	28	16	15	18	0,300	0,584
Avoiding fat	29	17	16	18	0,116	0,733
Eating smaller portions	97	56	40	74	20,247	0,0001
Physical exercise	35	20	20	20	0,001	0,972
Regularly consumed energy-reduced foods	90	52	33	73	27,104	0,0001
Kinds of energy-reduced foods regularly consumed by consumers						
Diet beverages	53	31	19	43	11,170	0,001
Low-fat dairy products	43	25	14	37	12,410	0,0001
Sugar-free products	37	22	7	37	23,041	0,0001
Fat-free products	26	15	5	26	15,692	0,0001
Low-fat products	49	29	17	40	11,581	0,001

(COS) did not differ significantly from the full-fat control muffins in terms of acceptability of appearance, colour and flavour, although they were scored significantly less acceptable in terms of texture and overall acceptance. The positive effect of a high fat content on the acceptability of baked products could be expected on the basis of other studies (Drewnowski, 1992, Fulton & Hogbin, 1993). Although highly acceptable, the muffins with 100% oil replacement by Simplesse® (CS) differed significantly on all the individual attributes from the full-fat control and COS muffins. These results are inconsistent with the results of a previous study among dietitians (Bosman *et al*, 1997) that showed no significant differences in acceptance between the full-fat control and the experimental muffins with Simplesse®.

Preference for muffins Consumer preferences for the different muffin formulations differed significantly and to a greater extent than acceptance. According to Figure 4 a statistically significantly higher percentage of consumers (45%) ($p \leq 0,05$) preferred the full-fat control muffins to those with partial oil replacement (COS), whereas the COS muffins were preferred by a significantly higher percentage of consumers than the muffins with total oil replacement (CS) ($p \leq 0,05$). Twenty-one per cent of the consumers did not prefer any of the muffins to any of the others. No signif-

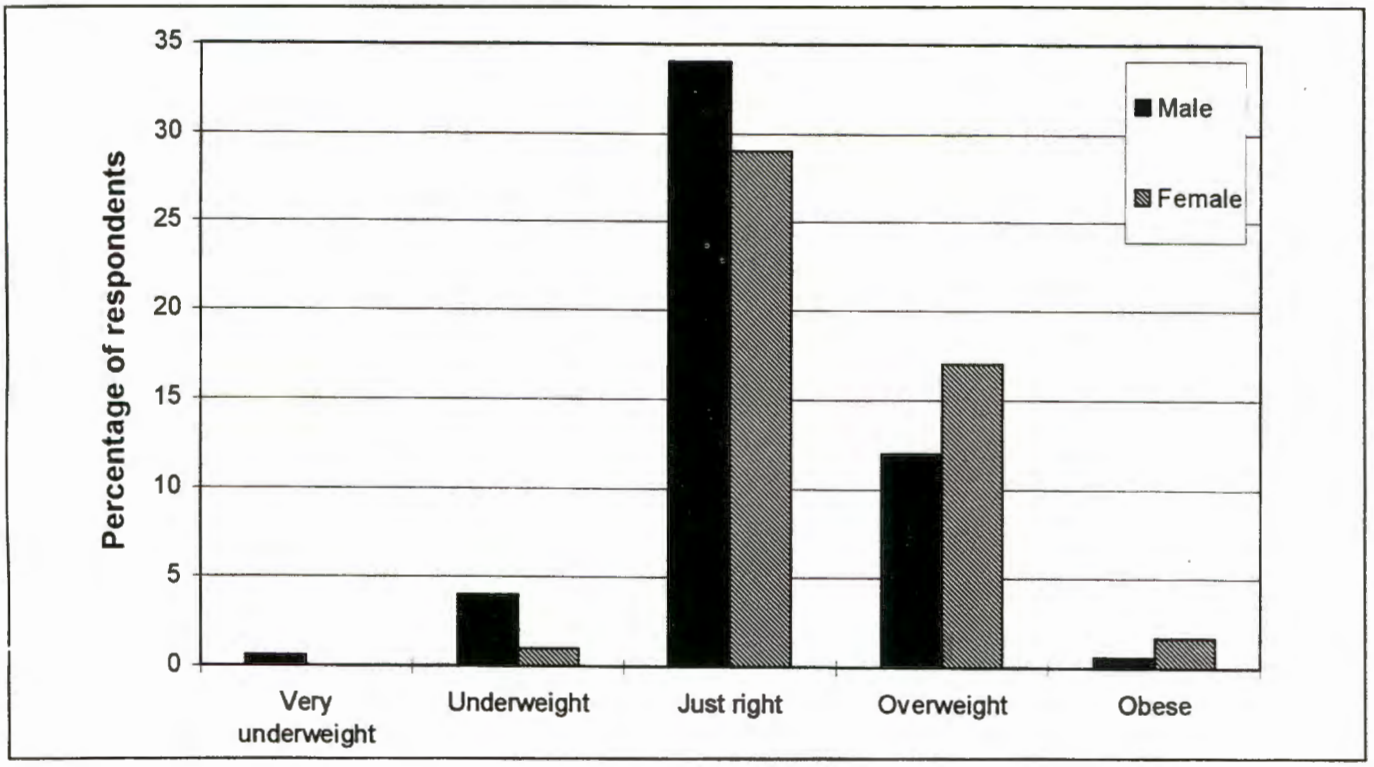

FIGURE 2: PERCEPTION OF BODY WEIGHT (N = 172)

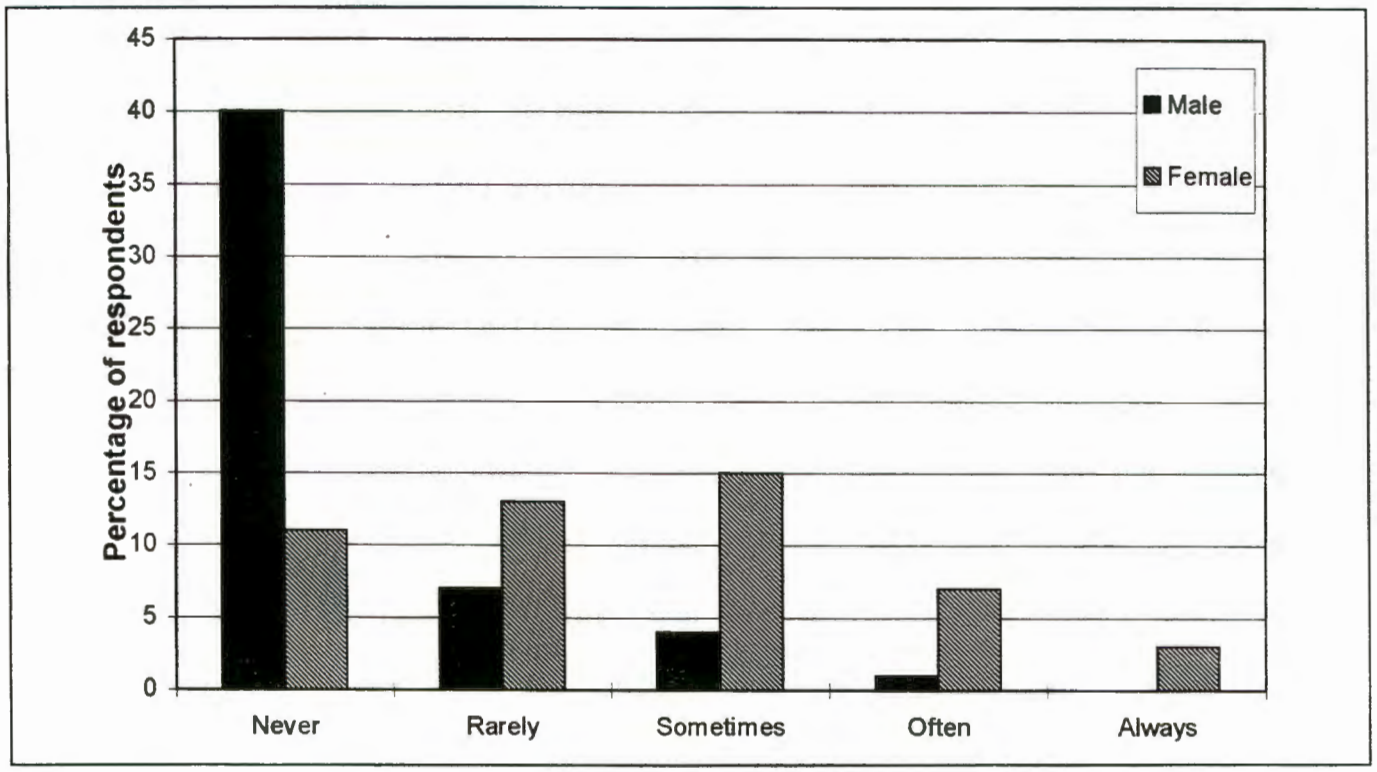

FIGURE 3: REPORTED FREQUENCY OF DIETING (N = 172)

icant differences in preference were established between gender or age groups.

According to Drewnowski (1997), a preference for high-fat foods appears to be a universal human trait. Children learn to prefer tastes, flavours and textures that are associated with high-energy density and they quickly learn to select foods that are either sweet, rich in fat, or both. Consumers are therefore conditioned to prefer fat-associated flavours and textures in foods (Mela & Marshall, 1991:44) and will

TABLE 3: ACCEPTANCE OF ATTRIBUTES AND INTENDED CONSUMPTION OF HIGH FIBRE MUFFINS (THREE FORMULAS, EVALUATED USING FIVE POINT HEDONIC * AND FOOD ACTION # RATING SCALES) (N = 172)

	Formulas		
	Formula C (control 100% oil)	**Formula COS (20% oil plus Simplesse®**	**Formula CS (only Simplesse®)**
	Mean ± SD	**Mean ± SD**	**Mean ± SD**
♦ **Acceptance***			
Appearance	4,30a ± 0,79	4,25a ± 0,62	3,95b ± 0,75
Colour	4,32a ± 0,75	4,28a ± 0,64	3,84b ± 0,84
Texture	4,37a ± 0,80	3,99b ± 0,65	3,75c ± 0,79
Flavour	4,43a ± 0,80	4,24a ± 0,65	3,95b ± 0,82
Overall acceptability	4,36a ± 0,60	4,19b ± 0,47	3,87c± 0,63
♦ **Consumption intent#**	4,27a ± 0,79	4,14a ± 0,71	3,77b ± 0,80

abc - Means with different superscripts in a row, differ significantly (p 0,001)

* 0-1 = Extremely unacceptable; 4-5 = Extremely acceptable

\# 0-1 = Will never eat 1-2 = Will eat only when no other food is available
2-3 = Will eat once a month 3-4 = Will eat once a week
4-5 = Will eat every day

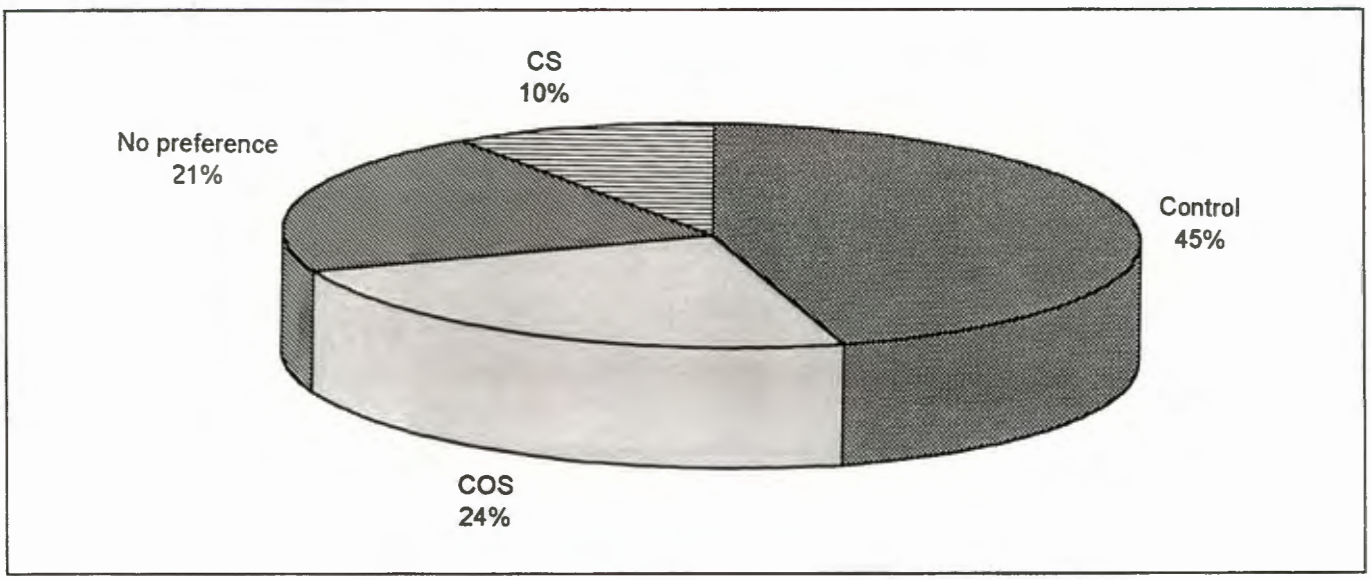

FIGURE 4: CONSUMER PREFERENCE OF MUFFIN VARIATIONS (N = 172)

typically prefer high-fat baked products to lower-fat versions (Drewnowski, 1987:251). These findings are consistent with those of Charlton and Sawyer-Morse (1996) who also found that consumers preferred full-fat chocolate chip cookies to those made with fat substitutes. These results differed, however, from those of a study among health professionals (dietitians) who did not prefer the full-fat control to the experimental muffins (Bosman *et* al, 1997).

Which sensory attribute drives preference? Food selection and preference are strongly influenced by sensory attributes such as the flavour and texture of foods, each of which is influenced greatly by the fat content of the foods (Drewnowski, 1997). A few studies have tried to determine the sensory attribute that was most important for preference of specific foods such as high-fibre muffins. Stepwise dis-

TABLE 4: THE INFLUENCE OF DEMOGRAPHIC AND WEIGHT CONTROL VARIABLES ON THE ACCEPTANCE AND INTENDED CONSUMPTION OF DIFFERENT MUFFIN FORMULAS (ANALYSED SIMULTANEOUSLY)

Variables	P-values	
	Acceptance	Consumption intent
Demographic		
Gender	0,0393*	0,3364
Age	0,9450	0,6814
Perception of own weight	0,5185	0,8418
Frequency of dieting to reduce weight	0,0849	0,3475
Practices to reduce weight		
Fasting	0,7846	0,2381
Skipping meals	0,5998	0,8271
Avoiding starch	0,5763	0,3370
Avoiding sugar	0,3917	0,0135*
Avoiding fat	0,2361	0,4502
Eating smaller portions	0,2993	0,9279
Physical exercise	0,3202	0,1545
Regular consumption of energy-reduced foods	0,5683	0,8674
Energy-reduced foods		
Diet beverages	0,8414	0,3789
Low-fat dairy products	0,1202	0,6501
Sugar-free products	0,0468*	0,1730
Fat-free products	0,1976	0,9940
Low-fat products	0,5015	0,8794

* $p \leq 0,05$

criminant analysis showed texture to be the most important sensory attribute in this study.

The relative importance of a sensory attribute is denoted by the change in the degree of acceptance or preference with small changes in the attribute level. Very important attributes are those where small changes in the attribute level, such as texture in this study, correspond with large changes in acceptance or preference. This finding is corroborated by a statement of Moskowitz and Jacobs (1987:294) who established that texture played a dominant role in the acceptance and preference of baked products. However, awareness of texture is usually at the subconscious level and is brought to the conscious level when expectations are violated by changes in the texture quality (Szczesniak, 1987:159).

Tenderness is one textural attribute that alters when fat in baked products is replaced or reduced (Setser & Racette, 1992). The analytical sensory results of a previous study by Bosman *et al* (1996) indicated that the tenderness of high-fibre muffins decreased significantly with increased oil replacement. The textural attributes provided by fat are therefore difficult to achieve with fat substitutes. The impact of fat replacement on the texture of the muffins was also noticeable in the consumer preferences. The less tender muffins with Simplesse® were less preferred because tenderness is a key attribute of texture. Textural properties

TABLE 5: SIGNIFICANT T-TEST RESULTS: INFLUENCE OF DEMOGRAPHIC AND WEIGHT CONTROL VARIABLES ON ACCEPTANCE [1] AND INTENDED CONSUMPTION [2] OF EACH MUFFIN FORMULA (INDIVIDUALLY ANALYSED)

Variables	Formula	Mean ± SD	P-value
Gender [1]			
Male	Full-fat control	4,26 ± ,58	
Female	Full-fat control	4,45 ± ,60	0,0386*
Energy-reduced foods [1]			
Sugar-free products			
Yes	Full-fat control	4,53 ± ,58	
No	Full-fat control	4,31 ± ,60	0,0488*
Practices to reduce weight [2]			
Avoiding sugar			
Yes	Full-fat control	4,64 ± ,68	
No	Full-fat control	4,19 ± ,79	0,0030**

* $P \leq 0,05$
** $P \leq 0,05$

may therefore represent the predominant contribution of fat to the sensory acceptance and preference of baked products (Mela & Marshall, 1991:44).

Intended consumption of muffins Consumers intended to eat the full-fat control and COS muffins significantly more regularly than the CS muffins (see Table 3). In spite of significant differences, the consumers revealed a positive attitude to all the muffin variations by declaring their intention to eat the control muffins and those with 80% replacement every day and those with 100% replacement of oil with Simplesse® once per week. However, no statistically significant differences in consumption intent were found between the full-fat control and the experimental muffins in the previous study among dietitians who intended to eat all the muffin variations once per week (Bosman *et* al, 1997).

Which sensory attribute drives consumption intent? As indicated by a previous study among dietitians (Bosman *et* al, 1997), flavour was the sensory attribute that best explained consumption intent regarding the muffin variations. This corresponds with the findings of Hatchwell (1994) and Barndt and Antenucci (1993:109,112) that satisfying taste is always a key attribute for overall product acceptance and frequent consumption and that taste will probably be a compelling motivational factor in driving consumption intent over time.

It is widely accepted that the sensory attributes contributed by fats constitute a critical factor in the acceptance and consumption of many foods. The pleasing flavour of high-fat foods enhances long-term food acceptability and therefore frequency of consumption. Fats modify the flavour of foods in unique ways, for example through naturally occurring flavour that is associated with the lipid component, through interaction, or through modification of the perception of existing or added flavour compounds. Fats do not just alter the maximum intensity of flavour, but also modify the timing and rate of onset and diminution of a flavour experience (Mela & Marshall, 1991:44). According to Hatchwell (1994), fat performs several functions in the flavour perception of food products. Reducing the fat content could therefore change the flavour profile. Using Simplesse® eases the task of flavour balancing, because it closely mimics the interaction of aroma chemicals with fat to develop low-fat muffins with a highly acceptable flavour, as illustrated in this study.

The hedonic preference and consumption intent data, however, did not always show the same tendency. Although the majority of consumers preferred the full-fat control muffins to the experimental muffins, they expressed their intention to eat the latter regularly. This could reflect a positive attitude to using Simplesse® in high-fibre muffins. These results also suggest that as the consumers knew that all the products that were tested were high in fibre content, health concerns could have been important determinants in food selection, perhaps more so than the sensory attributes of the muffins, provided that they were still acceptable (Guinard *et al*, 1996). Consumers could therefore have decided to consume a high-fibre product made with a fat substitutes for health reasons, even if attributes such as texture are not equivalent to the full-fat counterpart.

Influence of demographic and weight control variables on acceptance and intended consumption of muffins

According to the MANOVA results, the acceptance and intended consumption of the full-fat control muffins were influenced by two weight control variables, namely the use of

sugar-free products and avoidance of sugar respectively (Table 4).

Acceptance Statistically significant results were obtained for acceptance by the MANOVA for gender (p = 0,0393) and the use of sugar-free products (p = 0,0468). For gender only the full-fat control muffins showed a statistically significant difference (p = 0,0386) between the mean value of the males (4,26 ± 0,58) and the females (4,45 ± 0,60) (Table 5). In the case of energy-reduced foods, the mean acceptance score for the full-fat control C by the group who used sugar-free products (4,53 ± 0,58) differed significantly (p = 0,0488) from the score of those who did not use it (4,31 ± 0,60). As for the experimental muffins, none of the weight control variables had an effect on acceptance or intended consumption. The group of consumers who reported that they were using sugar-free products, scored the full-fat control muffins significantly higher in terms of acceptance than the group who did not use sugar-free products.

Consumption intent Only one significant MANOVA result (p = 0,0135) was obtained, namely that of avoiding sugar to reduce or control weight. Comparing the mean for intended consumption by the group who avoided sugar (4,64 ± 0,68) with that of the group who did not avoid sugar (4,19 ± 0,79), presented a statistically significant difference (p = 0,003) for full-fat C (Table 5). These results indicate that the group of consumers who reported avoiding sugar, intended to eat the control muffin significantly more frequently than the consumers who did not avoid sugar. This could be explained by the results of the descriptive panel who found the full-fat control muffins significantly less sweet than the experimental muffins baked with Simplesse® (Bosman *et al* 1996). The subjects who avoided sugar and used sugar-free products clearly preferred the less sweet product and intended to eat it more frequently.

CONCLUSION

Care should be taken in attempting to generalise these results as the subjects were representative of the target population defined as actual or potential users of high-fibre muffins. The 172 respondents who voluntarily participated in this study probably represented health-conscious consumers in view of their perceptions of body weight and their dietary practices to reduce or control body weight. The consumers preferred the full-fat control muffins and perceived it significantly more acceptable in terms of texture than the experimental muffins for which 80% of the oil had been replaced with Simplesse®. No further significant differences were identified between the control muffins and those with 80% Simplesse® replacement. This is consistent with a statement by Civille (1990) that Simplesse® was an effective fat substitute in developing highly acceptable low-fat products.

This study proved that although fat has multifunctional roles in a baked product, consumers would accept a variation on the traditional full-fat muffin, provided that none of the main sensory characteristics are sacrificed to any great extent. The sample consumers revealed a positive attitude to all the muffin variations by declaring their intention to eat the control muffins and the muffins with 80% replacement every day and those with 100% replacement of oil with Simplesse® once per week. According to the diet-related information obtained by means of the questionniare, the respondents also revealed a positive attitude to the consumption of energy-reduced foods, especially low-fat products. This was confirmed by their intention to eat the low-fat muffins with Simplesse® (CS) quite often. If fat replacement were to be accepted as a strategy for fat and energy reduction (Conforti *et al*, 1996), it is reasonable to assume that the low-fat, high-fibre muffins with Simplesse® would be a popular addition to the low-fat, energy-reduced foods that are available to these respondents. Weight control variables (with the exception of using sugar-free products and avoiding sugar) did not seem to influence the acceptance or intended consumption of the muffins.

This study emphasised that new developments in science and technology could be used to maintain the balance between nutrition and sensory acceptance by providing highly acceptable, nutritious, low-fat, high-fibre products for better compliance with prudent guidelines.

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CHAPTER 5

THE EFFECT OF STORAGE ON THE CHARACTERISTICS OF HIGH-FIBRE MUFFINS WITH DIFFERENT LEVELS OF A PROTEIN-BASED FAT SUBSTITUTE

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OPSOMMING

Die behoefte aan produkte wat aan die vereistes van die omsigtige dieet voldoen, noodsaak die ontwikkeling van hoëvesel-laevet-gebak. Vette, soos byvoorbeeld olie, speel egter 'n belangrike rol in die eetkwaliteit en raklewe van gebak en vermindering van die vetinhoud kan hierdie eienskappe nadelig beïnvloed. Tydens die ontwikkeling van laevet-produkte soek voedselwetenskaplikes dus na bestanddele met dieselfde funksies en interaksies as vet ten einde produkte met vergelykbare eienskappe en raklewe as dié van die volvetproduk te ontwikkel. Simplesse® Dry 100, 'n proteïngebaseerde vetvervanger, maak die ontwikkeling van laevet-hoëveselmuffins moontlik. Die hoër voginhoud van dié muffins mag egter moontlik hul raklewe beïnvloed, aangesien dit vogmigrering en vogverlies tydens opberging bevorder. Die effek van geen (volvetkontrole), 80%- en 100%- olievervanging met Simplesse® op die sintuiglike en fisiese eienskappe van hoëveselmuffins wat onderskeidelik vars gebak, by kamertemperatuur opgeberg (24 uur) of gevries (14 dae) en daarna ontdooi is, is ondersoek. Die effek van opberging op die verskillende muffinvariasies is ook bepaal. Sintuiglike evaluering van die voorkoms (bokorsvorm, -glans, -kleur, -oppervlak, kruimkleur), tekstuur (selverspreiding, -grootte, saamdrukbaarheid, korssagtheid, krummelrigheid, kruimsagtheid, klewerigheid en vogtigheid) en smaak is deur 'n analitiese proepaneel gedoen. Fisiese bepalings van saamdrukbaarheid (Instron), kleur (Minolta), persentasie vog en mikrobiologiese toetse (aerobiese mesofiele bakterie-plaattellings (AMP), giste en skimmels) is ook gedoen.

Olievervanging was die hoofbron van betekenisvolle variasie en het 'n statisties betekenisvolle effek ($p<0,01$) op al die sintuiglike en fisiese eienskappe behalwe selverspreiding, -grootte en vogtigheid binne al drie periodes van opberging getoon. Die varsgebakte eksperimentele muffins met Simplesse® is betekenisvol verskillend van die kontrole ten opsigte van voorkomseienskappe geëvalueer en het 'n meer simmetriese, effense geronde bokorsvorm, 'n effens glansende ligter bruin korskleur, 'n growwer

korsoppervlak en 'n ligter bruin kruimkleur as die kontrole getoon. Alhoewel die varsgebakte eksperimentele muffins nie ten opsigte van bokorsvorm en -oppervlak van mekaar verskil het nie, het dié met 100%-olievervanging 'n betekenisvolle ligter bruin kors- en kruimkleur gehad. Wanneer die voorkoms van die verskillende muffinvariasies na 24-uur opberging of nadat dit gevries en ontdooi is, vergelyk word, is dieselfde tendens as in die varsgebakte muffins waarneembaar. Die kontrolemuffins was na al drie periodes van opberging betekenisvol sagter, meer krummelrig en minder klewerig as dié met Simplesse®, alhoewel laasgenoemde ook sag en krummelrig was. Die varsgebakte muffins met 80%-olievervanging het nie van die kontrole verskil nie, maar dit was na opberging by kamer- en vriestemperature minder saamdrukbaar. Die muffins met totale olievervanging was egter, selfs vars gebak, minder saamdrukbaar as die kontrole en nog minder na opberging. Die smaak van die varsgebakte kontrole muffins en dié met Simplesse® het nie betekenisvol van mekaar verskil nie, maar na opberging is die muffins met 100%-olievervanging as betekenisvol soeter geëvalueer. Die fisiese bepalings van saamdrukbaarheid en kleur het meestal die sintuiglike resultate bevestig. Die persentasie voginhoud van die muffins het betekenisvol verhoog met toenemende persentasie olievervanging binne al drie periodes van opberging. Die gemiddelde totale AMP-tellings van die kontrole en eksperimentele muffins het nie betekenisvol van mekaar verskil binne enige van die periodes van opberging nie. Geen giste of skimmels is waargeneem nie.

Opberging by kamer- en bevriesingstemperature het die eienskappe van die muffins tot 'n mindere mate beïnvloed. Bokorsvorm, korsoppervlak, selverspreiding en selgrootte is nie betekenisvol deur opberging van enige van die muffinvariasies beïnvloed nie. Tydens opberging is enkele van die eienskappe van die kontrolemuffins betekenisvol ($p<0,01$) beïnvloed, terwyl meer van die eienskappe van die muffins met Simplesse® tydens die verskillende opbergingstoestande verander het. Die kontrolemuffins was effens donkerder, minder saamdrukbaar en fermer na 24-uur opberging. Dié wat gevries en ontdooi was, het egter betekenisvol van die varsgebakte en 24-uur opgebergde kontrole muffins verskil en het 'n nog donkerder kruimkleur en vogtiger tekstuur gehad.

Die muffins met 80%- sowel as dié met 100%-olievervanging het meeste van die "vars" eienskappe na 24-uur opberging behou, maar albei was donkerder, minder saamdrukbaar en fermer as die varsgebakte muffins. Dié muffins met 80%-olievervanging wat gevries

en daarna ontdooi was, was betekenisvol minder saamdrukbaar, fermer en vogtiger as die varsgebakte en minder krummelrig en meer klewerig as dié wat vir 24-uur opgeberg was. Die muffins met 100%-olievervanging was na bevriesing en ontdooiing minder saamdrukbaar, fermer, minder krummelrig, meer klewerig en minder vogtig as die 24-uur opgebergde muffins terwyl dit nie ten opsigte van al bogenoemde eienskappe van die varsgebakte muffins verskil het nie. Die tipiese smaak van die kontrolemuffins het nie tydens opberging verander nie hoewel beide eksperimentele muffins as soeter geëvalueer is nadat dit gevries en ontdooi was.

In teenstelling met die sintuiglike resultate het die Instron resultate getoon dat al die muffinvariasies meer saamdrukbaar was na bevriesing en ontdooiing as die vars- en 24-uur opgebergde muffins. Die effek van opberging op die voginhoud en bakterietelling van die verskillende muffinvariasies het verskil. Die kontrolemuffins het 'n laer voginhoud en hoër bakterietelling na 24-uur opberging gehad terwyl dié wat gevries was nie van die varsgebakte muffins verskil het nie. In teenstelling hiermee het die muffins met 80%-olievervanging geen verskille na 24-uur opberging of bevriesing getoon nie terwyl dié met totale olievervanging na beide opbergtoestande laer voginhoude en hoër bakterietellings gehad het. Hoewel die hoër bakterietellings nog binne die mikrobiologiese profiel van gebak val, word 'n afname in voginhoud oor die algemeen met 'n afname in "varsheid" van gebak (*staling*) geassosieer.

Die muffins met 80%-olievervanging het minder van die kontrole verskil en het meer van die vars eienskappe na 24-uur opberging by kamertemperatuur behou as dié wat gevries en daarna ontdooi was. Die muffins met 80%-olievervanging met Simplesse® word dus aanbeveel bo dié met 100%-vervanging, terwyl korttermyn opberging by kamertemperatuur bo langtermyn bevriesing vir hoëveselmuffins met Simplesse® aanbeveel word.

INTRODUCTION

Non-compliance with prudent guidelines regarding fat and fibre intakes by South Africans (Vorster *et al,* 1995) stimulated research to develop low-fat, high-fibre baked products of high quality. The importance of designing low-fat and low-kilojoule products is also clear from their 88% share of the total new bakery product introduction in the United States of America (Shukla, 1995). In selecting a high-fibre baked product, muffins are a good choice because high-moisture bakery products are better candidates for low-fat formulations (Shukla, 1995) and better carriers of high levels of cereal fibre like wheat bran than yeast-leavened pan bread (Daubenmire *et al,* 1993). Muffins are also well-known, convenient, easy to prepare and widely used by subjects who need to follow a low-fat diet. Bosman *et al* (1996; 1997) demonstrated, by means of a descriptive sensory panel and a consumer study, that the protein-based fat replacer, Simplesse® Dry 100, can successfully replace oil in freshly baked, high-fibre muffins baked from freshly prepared batter.

Health professionals and consumers are, however, not only interested in nutritious products with good eating qualities but are also concerned with the storage stability of the foods they consume (Spears, 1995:364; Best, 1991). Storage stability or shelf life of baked products could be defined as maintaining the sensory and physical characteristics associated with freshness such as crumb tenderness, compressibility and moistness by preventing deleterious changes associated with staling during storage (Paeschke, 1997; Guy, 1983; Zobel & Kulp, 1996:1). Staling indicates decreased consumer acceptance of bakery products caused by changes other than microbiological spoilage, including changes in taste and aroma, crumb firmness, compressibility and adhesiveness (Kulp & Ponte, 1981). A great deal of research has been carried out on the shelf life of bread, but only a few studies have addressed cake staling (Sych *et al*, 1987) and even fewer studies on the staling of muffins. Information regarding research on the effects of high-fibre content and fat replacement on the characteristics of muffins at different storage periods is limited in the literature. Since muffins prepared by the standard muffin method are best eaten freshly baked, they are usually prepared for immediate use or within the same day of baking, because they dry out when stored for any length of time (Freeland-Graves & Peckham, 1987:303). As wheat bran can greatly increase the water absorption of batter it may

increase and assist in maintaining crumb moistness and in improving shelf life. The incorporation of bran also improves tenderness in muffins because bran weakens the gluten structure by binding the water during pre-soaking, making less water available for glutenin and gliadin to form gluten (Daubenmire *et al,* 1993).

According to Conforti *et al* (1996) fat, such as oil, performs a major role in the eating and keeping quality of baked products by improving tenderness and moisture retention and extending the shelf life of cakes by inhibiting the premature loss of moisture and volatile flavour materials. A decrease in oil levels could have adverse effects on these attributes during storage. Low-fat baked products often have a shorter shelf life than their full-fat counterparts because the lubricity and mouthfeel provided by the oil is less and is often replaced by water and protein. The higher water content makes them more vulnerable to moisture migration, redistribution and moisture loss which contribute to increased crumb firmness and decreased consumer acceptance of baked products after storage (Paeschke, 1997; Sych *et al*, 1987). Problems common to low-fat foods also include loss of shelf life due to osmotic and water activity effects with storage (Shukla, 1995). Replacing oil with Simplesse® Dry 100 could, however, provide several functions of oil. As a protein, Simplesse® exhibits both hydrophilic and hydrophobic properties and acts as an emulsifier in baked goods. It contributes many textural benefits to fat-reduced or low-fat baked products such as binding water and promoting moistness and tenderness, which are important factors in improving storage stability (Corliss, 1992; The Nutrasweet Co., 1994). Foods with protein-based fat replacers should also be more characteristic of fat-containing products in flavour profile than products with other fat replacers, because the interaction of whey-based Simplesse® Dry 100 with flavour compounds is more like that of oil than other protein and carbohydrate fat substitutes (Schirle-Keller *et al*, 1992; Schirle-Keller *et al*, 1994).

According to Cauvain (1997) the storage stability of bakery products is limited due to loss of moisture, staling or microbiological growth, all linked together through the effects of water, its level, availability and mobility. While moisture content plays an important role in determining the rate at which products go mouldy or lose water, water activity (a_w) expresses the availability of water in food to take part in particular processes. The term a_w is often used interchangeably with the term equilibrium relative humidity (ERH), which is

100 times a_w and is expressed as a percentage. ERH and a_w are not controlled by the absolute moisture content of a product but rather by the quantities and nature of the soluble materials in the system and their ability to make water unavailable. The ERH of a product could be calculated with a computer-based programme called ERH CALC™ by simply using the formulation and a few process details (Cauvain, 1997). At temperatures around 25 °C, baked products such as cakes and muffins firm rapidly as the result of two separate processes, i.e. the firming effect caused by macroscopic moisture transfer from crumb to crust, and to a lesser extent the intrinsic firming of the cell wall material associated with starch recrystallisation and moisture redistribution among cake components during storage (Cauvain & Pateras; 1996; Guy, 1983). According to Willhoft (1973) the firming rate of cakes decreases as storage temperature decreases from 21 °C to -1 °C, which seems to suggest that starch has little to do with cake staling. Actual moisture content, as well as any ingredient that contributes to the consumer's perception of moistness, for example, fats and emulsifiers, contribute to the apparent freshness of cakes. Dehydration of the cake crumb is perceived to play an important role in the sensory evaluation of cake staleness, although cakes undergo firming even at constant moisture (Willhoft, 1973). As a general rule, the higher the practical moisture content of the fresh product, the more pronounced are the changes that occur upon staling. Products such as cakes stale to a much greater extent than do products such as biscuits (Kamel & Ponte, 1993:180). According to Cauvain (1997) water management seems to be the key to extended shelf life of baked products.

Frozen baked products enjoy a fresh and safe image and are associated with quality, provided that product integrity is preserved by controlling the cold chain from production to thawing. If the main objectives in freezing, namely to protect products from deterioration and to extend their storage lives by reducing staling, were achieved, there is little change in appearance, texture, flavour and nutritional value of frozen-thawed products. The quality of frozen-thawed products will, however, be affected by factors such as the nature and quality of the product at the time of freezing, freezing conditions, storage times and temperatures, packaging and thawing conditions (Cauvain & Pateras, 1996). Rapid freezing, defined as a process by which the temperature of baked products is lowered to about –20 °C within 2 hours, favours formation of a great number of small ice crystals, which is vital for maintaining product quality. Cauvain and Pateras (1998) have

indicated that as the soluble substances in cakes, such as sugars and salts, depress the freezing point to around -18 °C, some bakery products are not totally frozen even at -40 °C. While frozen storage temperature is the single most important factor in determining the rate of change in the textural properties of cakes and muffins during frozen storage, a temperature below -18 °C, without or with limited fluctuation, is recommended, where changes would occur at a very low rate and ice crystal growth which could cause structure distortion is limited (Cauvain & Pateras, 1998:11). Thawing is a much slower process than freezing and could provide ample opportunity for moisture migration and staling, especially during subsequent ambient storage of the thawed product if not consumed soon. Wrapping baked products before freezing minimises moisture loss but could also reduce the freezing rate if a slow freezing process is used. The relatively higher concentration of water-soluble substances in cake and muffin batters results in lower water activities than bread dough, which ensures that muffins are less prone to moisture migration and loss during freezing. Cakes can thus be successfully frozen without major changes in quality (Cauvain & Pateras, 1996).

Information on the effect of oil replacement and storage on the quality of high-fibre muffins could also be important for application in food services. An increasing number of food services are using advance production of products during slack periods to equalise work loads. If some menu items such as high-fibre low-fat muffins could be prepared and baked one or two days ahead or could be frozen and thawed in time without adverse effects on quality or safety, it will ensure efficient use of employee time, equipment and availability of a much needed food item (Payne-Palacio *et al,* 1997:140).

OBJECTIVE

The objective of this study was to evaluate the effect of storage period and temperature on the sensory and physical characteristics and microbiological counts of high-fibre muffins with different percentages of oil replacement. Muffins stored at room temperature for 24 hours, and muffins frozen and thawed were compared with freshly baked muffins.

MATERIALS AND METHODS

The experimental design for this study is given in Figure 1.

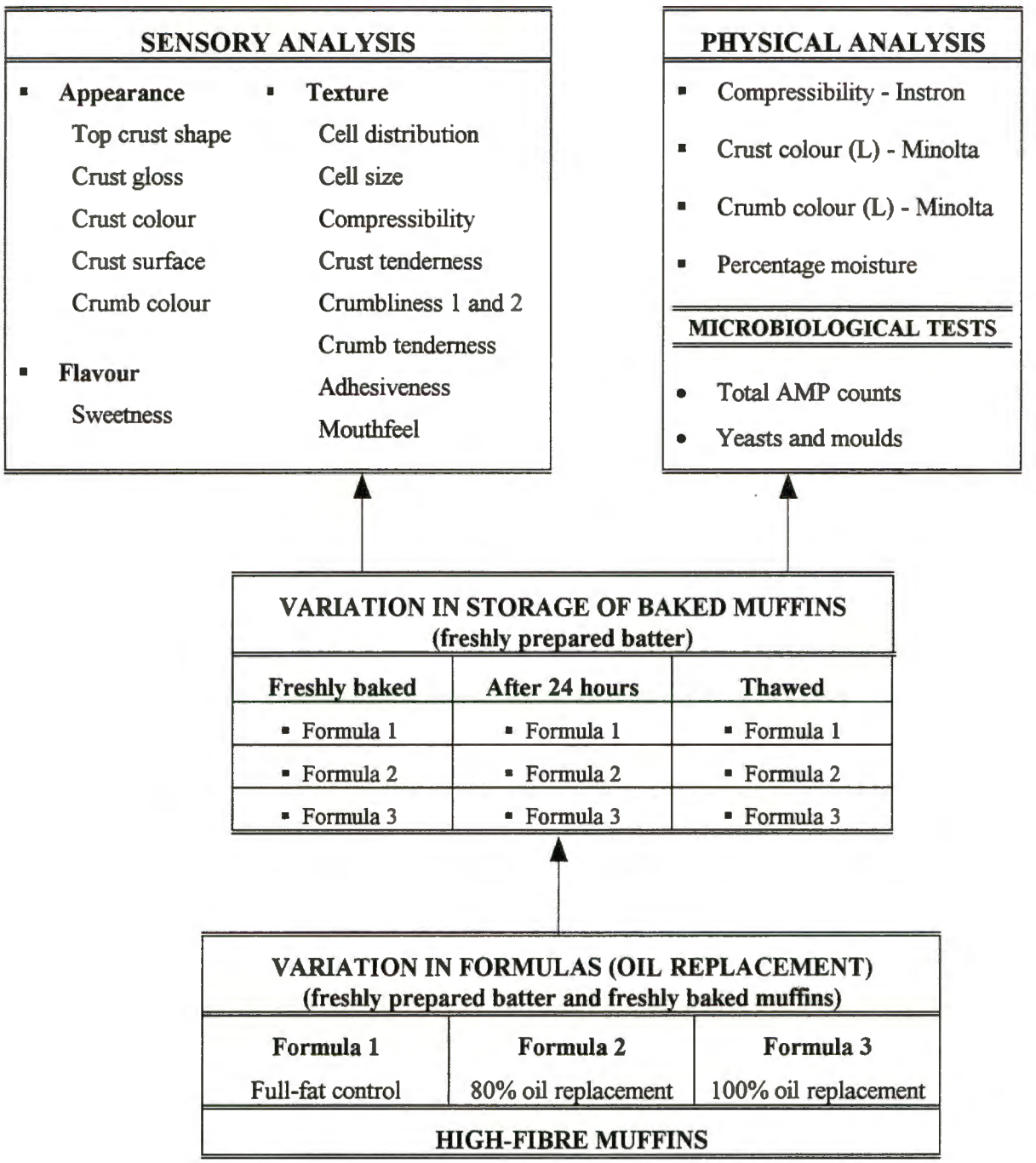

FIGURE 1: EXPERIMENTAL DESIGN – The effect of oil replacement and storage on the characteristics of high-fibre muffins

Muffin preparation and storage

High-fibre muffins with zero, 80% and 100% oil replacement with Simplesse® (full-fat control - Formula 1, Formula 2 and Formula 3 respectively), were freshly mixed, baked and cooled as described by Bosman *et al* (1996). After being cooled for one hour the muffins from each formula were wrapped in moisture and vapour-proof plastic wrap and packaged in plastic bags coded according to the formula and three storage periods. Muffins to be evaluated 2 and 26 h after baking, were stored at room temperature. Those evaluated two weeks (14 days) after baking were frozen in an ultra low temperature storage freezer (Forma Scientific Bio-freezer) at -40 °C by a slow still freezing process whereby the temperature of -40 °C was achieved within 5-8 h and maintained. The frozen samples were thawed covered at room temperature for 12 h and then uncovered 2 h prior to testing (slow thawing). The order of selection of muffins for various sessions and the order of presentation of samples were prearranged according to an incomplete balanced-block design. Four replications were conducted for the various physical and sensory tests on samples randomly selected from the same batch for each session.

The equilibrium relative humidity (ERH) values for the three formulas were calculated by means of the ERH CALC™ computer programme (Copyright Flour Milling and Baking Research Association (FMBRA), Campden and Chorleywood, United Kingdom).

Sensory evaluation

Sensory analysis were conducted by an analytical descriptive panel (8 panellists) selected and trained as described by Bosman *et al* (1996). Concern about some hedonic terms and a few possible confounded scales used during the previous study necessitated further training of the panel based on standardised methods (Setser, 1994; Lawless & Heymann, 1998:363). This training included revising and defining attributes with anchors as summarised in Table 1. A six-point Likert-type rating scale, where 1 represents the minimum and 6 the maximum intensity of each attribute, was used. Evaluations were conducted in partitioned booths in 10 sessions over a 5-week period under controlled conditions.

TABLE 1: SENSORY ATTRIBUTES, DEFINITIONS AND SCALE ANCHORS USED TO EVALUATE THE SENSORY CHARACTERISTICS OF HIGH-FIBRE MUFFINS

	Sensory characteristic	Attribute	Definition	Scale anchors*
1	**Appearance**	1.1 Top crust shape/ Top surface symmetry	Symmetry or evenness of cross-section of muffin viewed from the side, ranging from uneven (asymmetrical) to even (symmetrical)	Uneven/even
		1.2 Crust gloss	Amount of light reflected from the product's surface (none/very much)	Dull/glossy
		1.3 Crust colour lightness	Darkness/lightness of browned crust surface (high score indicates light brown)	Dark/light
		1.4 Crust surface roughness	The amount of irregularity, protrusions or bumps (pebbles) which can be seen on the surface (smoothness is the absence of surface irregularity)	Smooth/coarse (pebbled)
		1.5 Crumb colour lightness	Darkness/lightness of browned crumb (high score indicates light brown)	Dark/light
2	**Texture**	2.1 Cell distribution	Evenness or degree of uniformity of cells within the crumb	Nonuniform/uniform, or uneven/even
		2.2 Cell size	Cell size and number of cells that make cut surface (crumb) appear either dense and compact or light and open (loose or airy)	Small/large
		2.3 Compressibility	How readily the sample could be compressed between the finger tips	Not easily compressed/ easily compressed
		2.4 Crust tenderness	How readily/easy the crust could be bitten through (not readily/readily)	Not tender/tender
		2.5 Mouthfeel - crumb moisture	Amount of moisture in crumb that is released upon chewing (small = dry/large = moist)	Dry/moist
		2.6 Crumbliness at initial bite	The degree to which the sample breaks loose (separates) and crumbles rather than deforms and holds together at initial bite (slight/strong)	Cohesive/crumbly
		2.7 Crumbliness after chewing	The degree to which the sample breaks loose and crumbles (falls to pieces) rather than clumps together in a ball-like mass after 6 to 8 chews (slight/strong)	Cohesive/crumbly
		2.8 Crumb tenderness	How readily the crumb breaks off on initial bite (not readily/readily)	Not tender/tender
		2.9 Adhesiveness (tooth packing)	Degree to which chewed material adheres or sticks to teeth or mouth surface after mastication (strong/slight)	Adhesive/not adhesive
3	**Flavour**	3.1 Typical	Nutty, slightly sweet taste (without taint or aftertaste)	Atypical/typical
		3.2 Sweet	Fundamental taste factor	Weak/strong
		3.3 Nutty	Nonspecific nut-like aromatic note	Slight/strong

* Scale ranges from 1 (minimum) to 6 (maximum intensity) for all attributes, except for adhesiveness where a high rating represents the absence of or minimum intensity

Two series of three samples each (one sample per formula) were presented individually on small white coded plates on a white tray. Water at room temperature was provided for mouth rinsing before and between each of the three samples in a series. Apple slices were served in the 10 min break between the two series of each session.

Physical determinations

Compressibility was determined by using an Instron Universal Testing Machine (model MNN 44) equipped with a flat plunger (21 mm diameter) compressing a sample of 25 mm thickness at a crosshead speed of 100 mm/min to 40% of the original height. The reading was taken at the force (Newton) necessary to compress the sample 25% (6,25 mm). One reading per sample was taken on four samples per batch per formula at each storage period. The exact sample was obtained by cutting a slice of 25 mm vertically from the centre of each muffin.

Colour was measured by obtaining lightness (L) values for the external top surface (crust colour) and internal cut surface (crumb colour) of four muffins per formula per storage time using a Minolta colorimeter (model CR200) which was set versus a white reference tile (L=97,79, a=-5,55 and b=+7,35).

Moisture content of muffins was determined in duplicate for each batch (2x4) using the AOAC method 22-8 (AOAC, 1984).

Microbiological counts

Total aerobic mesophilic plate count (AMP) of viable bacteria as well as yeasts and moulds were done in duplicate on each sample of baked muffins collected per session. The tests were done according to the Standard Methods of the SA Bureau of Standards (SABS), namely SABS Method 756 and ISO method 7954, respectively. The microbial counts are reported as colony forming units per gram (CFU/g).

Statistical analyses Two-way and one-way analyses of variance (ANOVA) and Tukey's multiple comparison tests ($p<0,05$) were applied to the sensory, physical and microbiological data to determine whether the muffins from the different formulas differed significantly within each of the storage periods or within each formula at the different storage periods. The relationship between the sensory and physical variables was analysed

by means of Pearson's product-moment correlations. Cluster analysis was separately performed on the sensory and physical data by linking the types by the average linking method using the Euclidian distances between the types. The SAS Institute, Inc. (1988) programme was used for data analyses.

RESULTS AND DISCUSSION

This study involves basic research which could contribute important information for other researchers in this field. Therefore, an extensive discussion of the results will be given, followed by a conclusion which will focus on the significance and original contribution of the study.

Analysis of variance of the sensory, physical and microbial results are summarised in Tables 2 and 3. Table 2 demonstrates how the characteristics of the high-fibre muffins with different levels of oil replacement differed when freshly baked, when stored at room temperature and when frozen-thawed, respectively, while Table 3 compares the effects of different storage conditions on the characteristics of the muffins within each formula. The results revealed that oil replacement, as one of the independent variables, was the major source of significant variation in this study, while storage showed significant variations to a minor extent. Since cell size and cell distribution were not significantly affected by either the replacement of oil or storage and the mean ratings showed very small variations (between 5,1 and 5,3 for both) these results were not presented in Tables 2 and 3. No yeasts or moulds were detected in any of the samples analysed irrespective of oil replacement or storage period. The calculated ERH values of the three formulas were 95%, showing no difference.

TABLE 2: MEAN VALUES FOR SENSORY† AND PHYSICAL▲ CHARACTERISTICS AND TOTAL BACTERIAL COUNTS OF HIGH-FIBRE MUFFINS WITH DIFFERENT LEVELS OF OIL REPLACEMENT AT THREE STORAGE PERIODS AND BAKED FROM FRESHLY PREPARED BATTER

	APPEARANCE#					TEXTURE#							FLAVOUR#	PHYSICAL				TOTAL AMP COUNT CFU/g
	Top crust shape	Crust gloss	Crust colour lightness	Crust surface	Crumb colour lightness	Compress-ibility	Crust tenderness	Crumbliness initial bite	Crumbliness after chewing	Crumb tenderness	Adhesiveness	Mouthfeel moistness		Compress-ibility (Newton)	Crust colour (L)	Crumb colour (L)	Moisture (%)	
Significance (2 x ANOVA)																		
Formula (F)	***	***	***	***	***	***	***	***	***	***	***	NS	***	***	***	***	***	NS
Muffin storage (S)	NS	***	***	NS	***	***	***	**	***	***	**	**	***	***	NS	*	***	***
F x M	NS	NS	***	NS	***	NS	***	***	*	NS	*	***	NS	NS	NS	NS	NS	NS
Freshly baked muffins																		
100% oil (control)	$4,9^{b}$	$4,8^{c}$	$4,0^{c}$	$4,9^{b}$	$4,0^{c}$	$5,4^{a}$	$6,0^{a}$	$5,9^{a}$	$5,8^{a}$	$5,8^{a}$	$5,8^{a}$	$4,3^{a}$	$5,3^{a}$	$5,0^{c}$	$35,2^{b}$	$40,0^{c}$	$38,2^{b}$	$5,0 \times 10^{2}$
80% oil replacement◆	$5,8^{a}$	$5,9^{a}$	$4,9^{b}$	$5,7^{a}$	$4,9^{b}$	$5,0^{ab}$	$5,8^{b}$	$5,5^{b}$	$5,2^{b}$	$5,2^{b}$	$5,4^{b}$	$4,5^{a}$	$5,3^{a}$	$6,3^{b}$	$37,6^{ab}$	$42,6^{b}$	$42,4^{a}$	$5,3 \times 10^{2}$
100% oil replacement	$5,6^{a}$	$5,5^{b}$	$5,5^{a}$	$5,4^{a}$	$5,2^{a}$	$4,8^{b}$	$5,1^{c}$	$5,0^{c}$	$4,9^{c}$	$5,0^{b}$	$4,9^{c}$	$4,5^{a}$	$5,0^{a}$	$7,0^{a}$	$40,9^{a}$	$46,6^{a}$	$44,1^{a}$	$5,3 \times 10^{2}$
Significance	***	***	***	***	***	**	***	***	***	***	***	NS	NS	***	**	***	***	NS
Muffins stored 24 hours																		
100% oil (control)	$5,1^{b}$	$4,6^{b}$	$3,2^{c}$	$5,2^{a}$	$3,4^{c}$	$5,1^{a}$	$5,9^{a}$	$5,8^{a}$	$5,8^{a}$	$5,4^{a}$	$5,8^{a}$	$3,9^{a}$	$5,4^{a}$	$5,1^{c}$	$35,4^{a}$	$39,7^{c}$	$36,2^{c}$	$3,3 \times 10^{3}$
80% oil replacement	$5,8^{a}$	$5,7^{a}$	$4,4^{b}$	$5,6^{a}$	$4,6^{b}$	$4,5^{b}$	$5,5^{b}$	$5,4^{b}$	$5,5^{b}$	$4,6^{b}$	$5,5^{b}$	$4,3^{a}$	$5,1^{ab}$	$6,3^{b}$	$36,7^{a}$	$44,2^{b}$	$41,9^{b}$	$3,0 \times 10^{3}$
100% oil replacement	$5,4^{b}$	$5,5^{a}$	$5,0^{a}$	$5,3^{a}$	$5,0^{a}$	$4,4^{b}$	$5,2^{b}$	$5,1^{c}$	$5,1^{c}$	$4,3^{b}$	$5,2^{b}$	$4,5^{a}$	$4,7^{b}$	$7,1^{a}$	$37,6^{a}$	$46,7^{a}$	$43,1^{a}$	$3,7 \times 10^{3}$
Significance	***	***	***	NS	***	***	***	***	***	***	***	NS	***	***	NS	***	***	NS
Muffins stored frozen 14 days																		
100% oil (control)	$4,9^{b}$	$4,6^{b}$	$3,0^{c}$	$5,0^{b}$	$3,1^{c}$	$4,9^{a}$	$5,9^{a}$	$5,9^{a}$	$5,8^{a}$	$5,2^{a}$	$5,8^{a}$	$4,6^{a}$	$5,1^{a}$	$4,6^{b}$	$34,8^{b}$	$41,0^{b}$	$37,3^{c}$	$2,7 \times 10^{3}$
80% oil replacement	$5,6^{a}$	$5,5^{a}$	$4,4^{b}$	$5,5^{a}$	$4,5^{b}$	$4,3^{b}$	$5,1^{b}$	$5,0^{b}$	$5,0^{b}$	$4,3^{b}$	$5,1^{b}$	$4,1^{a}$	$4,8^{ab}$	$5,6^{a}$	$38,4^{a}$	$45,3^{a}$	$41,1^{b}$	$2,7 \times 10^{3}$
100% oil replacement	$5,6^{a}$	$5,4^{a}$	$5,1^{a}$	$5,7^{a}$	$4,8^{a}$	$4,0^{c}$	$4,9^{b}$	$4,8^{c}$	$4,7^{c}$	$4,0^{b}$	$4,8^{b}$	$4,0^{a}$	$4,4^{b}$	$5,8^{a}$	$39,2^{a}$	$48,3^{a}$	$42,7^{a}$	$2,7 \times 10^{3}$
Significance	***	***	***	***	***	***	***	***	***	***	***	NS	**	***	**	***	***	NS

† Each mean average of n = 32 (8 panellists x 4 replications).
\# Intensity scale 1 = minimum, 6 = maximum, except for adhesiveness where the scale was reversed
▲ Each mean average of n = 16 (4 per batch x 4 replications)
◆ Fat substitute Simplesse® Dry 100
abc Mean values in each column block with different superscripts differ significantly regarding formula

NS Not significant
* $p \leq 0,05$
** $p \leq 0,01$
*** $p \leq 0,001$

* **Effect of oil replacement (formula) on sensory and physical characteristics of muffins within each period of storage (shelf life).**

According to the results (Table 2), oil replacement (formula) had a statistically significant effect ($p \leq 0,01$) on all the characteristics of the muffins except cell size, cell distribution, mouthfeel (moistness) and total AMP count of bacteria as determined within each of the different periods of storage, namely freshly baked, stored for 24 h at room temperature or thawed after being frozen for 14 days. No significant differences were found between the mean total AMP counts of the muffins within each storage period varying between 5,0 x 10^2 and 3,7 x 10^3 CFU/g which falls within the normal range or microbiological profile of baked products (Elliot, 1980:696; Vanderzant & Splittstoesser, 1992:999).

Sensory analysis Comparing the freshly baked muffins of the different formulas for *appearance,* the experimental muffins with oil replacement (Formulas 2 and 3) were rated significantly different, for having a more symmetrical, even, slightly rounded crust shape, a glossy, lighter brown crust colour, a pebbled coarse crust surface and a lighter brown crumb colour compared to the less even, dull, darker brown, less pebbled, full-fat control muffins. Although no significant differences were observed between the freshly baked experimental muffins with regard to top crust shape and surface, the muffins with total oil replacement (formula 3) had a significantly less glossy, lighter brown crust and lighter crumb colour than those with partial oil replacement (formula 2). This is in agreement with the results of Conforti *et al* (1996) which also indicated a decrease in browning as the percentage of fat substitute increased.

Comparing the *appearance* of the muffins from the different formulas after 24 h storage at room temperature or after being frozen-thawed, the same tendency of differences as in the freshly baked muffins was observed. The experimental muffins made with the protein-based fat substitute were also rated significantly different from the full-fat control muffins on all the attributes of appearance except for crust surface, which did not differ from the full-fat control after 24 h storage. Crust and crumb colour lightness increased significantly as the level of oil replacement increased at both storage periods.

The full-fat control muffins, however, were rated significantly different on most of the attributes of *texture* at all three selected periods of storage, namely for being more crumbly

and tender (crust and crumb) and less adhesive than the experimental muffins. It must be noted, however, that although significantly different, the crumb of the muffins made with the fat substitute was only slightly less crumbly and less tender and slightly more adhesive (sticky) than the full-fat control muffins (with the lowest rating still as high as 4,0 after frozen storage). These results correspond with some of the findings of Conforti and Smith (1998) which also showed fat-reduced muffins with fat substitute to be less crumbly than the control. No significant differences in crumb tenderness were found among the muffins with partial and total oil replacement at any of the three different periods of storage. Although the muffins with partial oil replacement did not differ significantly from the full-fat control on compressibility when freshly baked, they were less compressible after storage at room and freezer temperatures while those with 100% oil replacement were significantly less compressible than the full-fat control freshly baked and after both storage periods. The difference in crumb tenderness between the experimental and full-fat muffins seems to be even greater after both storage periods than freshly baked, indicating that, although the higher moisture content of the experimental muffins promoted initial tenderness, it did not enhance final tenderness after storage to the same extent. Crumbliness of the crumb decreased significantly with increased oil replacement at all three storage periods. Although the freshly baked muffins with partial oil replacement were less adhesive and their crusts were more tender than the muffins with total oil replacement, no significant differences existed after storage. The fact that the panellists did not perceive any differences in mouthfeel (moistness) between the full-fat control and the experimental muffins within any of the selected storage periods confirms the statement of Corliss (1992) regarding the benefit of Simplesse® in promoting moistness in low-fat baked products.

The *flavour* of the full-fat control muffins did not differ significantly from the experimental muffins when freshly baked and was described as typical, with a nutty and slightly sweet taste. This confirms the findings of Sloan and James (1988) that the incorporation of high levels of baked wheat bran yielded muffins with a nutty flavour. It also confirms the statement of Schirle-Keller *et al* (1994) that foods with protein-based fat substitutes should have a flavour profile similar to fat-containing products. After being stored at room temperature (24 hours) or at freezer temperature (14 days) the muffins with 100% oil replacement were, however, rated significantly different from the full-fat control

muffins on flavour, because the panellists indicated that sweetness was more perceptible. Rating sweetness, as fundamental taste factor, however, showed the muffins with 100% oil replacement to be significantly sweeter when freshly baked and after frozen storage than when 24 h stored.

Physical determinations *Compressibility* was measured instrumentally as the force required to attain a specified compression (25%) of a sample of specific thickness (25 mm). Thus, the firmer the sample, the higher the force required and vice versa. According to Table 2 the experimental muffins required significantly more force to be compressed as the level of oil replacement increased, being significantly firmer or less compressible than the full-fat control muffins within all three periods of shelf life. This confirms the sensory results on compressibility and agrees with the results of Cauvain (1991) which also indicated increased firmness of cakes with additional protein and reduced fat levels. These results also correspond with the findings of Conforti and Smith (1998) which showed that crumb tenderness of muffins decreased when oil was replaced with a fat substitute. According to the Instron results, the muffins with partial oil replacement were significantly more compressible than those with total oil replacement when freshly baked and after 24 h storage but not after frozen storage. These differences were, however, not confirmed by the sensory panel.

Crust and crumb colour (lightness: L-values) Results on instrumental analysis of colour lightness (L-values) of the external (crust) and internal (crumb) surfaces are also shown in Table 2. No significant differences were found between the crust colour of full-fat control and the muffins with 80% oil replacement on lightness (L-values) which were instrumentally obtained from freshly baked and 24 h stored muffins. The crust colour of muffins with 100% oil replacement, freshly baked and frozen-thawed, was significantly lighter than the full-fat control, while no significant differences were found between the control and experimental muffins after 24 h storage. The crumb colour of both formulas with protein-based fat substitute was significantly lighter than the full-fat control muffins at all three storage periods, confirming the sensory results. These results correspond with the findings of Conforti and Smith (1998) who also reported a significantly lighter crumb colour in muffins with a fat substitute than the full-fat control.

Moisture content In correspondence with the findings of Conforti and Smith (1998) the moisture content increased significantly in both experimental muffins with Simplesse®. This could be due to the additional water in the experimental formulations necessary for hydration of Simplesse® Dry 100 and its water retention ability because of its polar character to bind water molecules through hydrogen bonds. Although not significantly different when freshly baked, the experimental muffins differed significantly from each other after storage at room and freezer temperatures. These significant differences in physical determination of moisture content were, however, not confirmed by the panellists' perception of sensory moistness. Although the fat-reduced muffins were higher in moisture content, the panellists did not perceive them to be moister. Oil contributes to lubricity during mastication and creates an easier and smoother breakdown of the baked product, reducing the amount of saliva required for mastication and swallowing of the food item. The full-fat product could thus be perceived to be as moist, although lower in moisture content, than the fat-reduced product (Conforti & Smith: 1998).

***Effect of storage on the characteristics of the muffins within each formula**

Sensory analysis While storage of the baked muffins did not significantly affect top crust shape, crust surface, cell distribution or cell size in any of the formulas, both storage at room and freezer temperature conditions showed small but significant effects on crust and crumb colour lightness, compressibility, crumb tenderness and mouthfeel within all the formulas as compared to their freshly baked counterparts (Table 3).

Comparing the freshly baked and stored muffins within each formula on *appearance* resulted in only a few significant differences. The crust and crumb colour of the full-fat control muffins were significantly darker after storage at both room and freezer temperature conditions than freshly baked. Although not darker, both experimental muffins also showed a significant decrease in crust and crumb colour lightness after storage at both temperatures. In addition, the muffins with partial oil replacement were less glossy after freezing than freshly baked, while the full-fat control and muffins with total oil replacement showed no differences on crust gloss after storage.

TABLE 3: MEAN VALUES FOR THE SENSORY† AND PHYSICAL▲ CHARACTERISTICS AND TOTAL BACTERIAL COUNTS OF HIGH-FIBRE MUFFINS IN THREE FORMULAS EACH AT THREE STORAGE PERIODS BAKED FROM FRESHLY PREPARED BATTER

	APPEARANCE#					TEXTURE#								PHYSICAL				
	Top crust shape	Crust gloss	Crust colour lightness	Crust surface	Crumb colour lightness	Compress-ibility	Crust tenderness	Crumbliness initial bite	Crumbliness after chewing	Crumb tenderness	Adhesiveness	Mouthfeel moistness	FLAVOUR#	Compress-ibility (Newton)	Crust colour (L)	Crumb colour (L)	Moisture (%)	TOTAL AMP COUNT CFU/g
Formula 1: Full-fat control																		
Freshly baked	4,9	4,8	$4,0^{x}$	4,9	$4,0^{x}$	$5,4^{x}$	6,0	5,9	5,8	$5,8^{x}$	5,8	$4,3^{y}$	5,3	$5,0^{x}$	35,2	40,0	$38,2^{x}$	$5,0 \times 10^{2}{}_{y}$
Stored 24 hours	5,1	4,6	$3,2^{y}$	5,2	$3,4^{y}$	$5,1^{xy}$	5,9	5,8	5,8	$5,4^{y}$	5,8	$3,9^{z}$	5,4	$5,1^{x}$	35,4	39,7	$36,2^{y}$	$3,3 \times 10^{3}{}_{x}$
Stored frozen 14 days	4,9	4,6	$3,0^{y}$	5,0	$3,1^{z}$	$4,9^{y}$	5,9	5,9	5,8	$5,2^{y}$	5,8	$4,6^{x}$	5,1	$4,6^{y}$	34,8	41,0	$37,3^{xy}$	$2,7 \times 10^{3}{}_{xy}$
Significance	NS	NS	***	NS	***	**	NS	NS	NS	***	NS	***	NS	*	NS	NS	*	*
Formula 2: 80% oil replacement◆																		
Freshly baked	5,8	$5,9^{x}$	$4,9^{x}$	5,7	$4,9^{x}$	$5,0^{x}$	$5,8^{x}$	$5,5^{x}$	$5,2^{xy}$	$5,2^{x}$	$5,4^{x}$	$4,5^{x}$	$5,3^{x}$	$6,3^{x}$	37,6	$42,6^{y}$	42,4	$5,3 \times 10^{2}{}_{x}$
Stored 24 hours	5,8	$5,7^{xy}$	$4,4^{y}$	5,6	$4,6^{y}$	$4,5^{y}$	$5,5^{x}$	$5,4^{x}$	$5,5^{x}$	$4,6^{y}$	$5,5^{x}$	$4,3^{xy}$	$5,1^{xy}$	$6,3^{x}$	36,7	$44,2^{xy}$	41,9	$3,0 \times 10^{3}{}_{x}$
Stored frozen 14 days	5,6	$5,5^{y}$	$4,4^{y}$	5,5	$4,5^{y}$	$4,3^{y}$	$5,1^{y}$	$5,0^{y}$	$5,0^{y}$	$4,3^{y}$	$5,1^{y}$	$4,1^{y}$	$4,8^{y}$	$5,6^{y}$	38,4	$45,3^{x}$	41,1	$2,7 \times 10^{3}{}_{x}$
Significance	NS	**	***	NS	***	***	***	**	***	***	**	*	**	*	NS	*	NS	NS
Formula 3: 100% oil replacement																		
Freshly baked	5,6	5,5	$5,5^{x}$	5,4	$5,2^{x}$	$4,8^{x}$	$5,1^{xy}$	$5,0^{xy}$	$4,9^{xy}$	$5,0^{x}$	$4,9^{xy}$	$4,5^{x}$	$5,0^{x}$	$7,0^{x}$	$40,9^{x}$	46,6	$44,1^{x}$	$5,3 \times 10^{2}{}_{y}$
Stored 24 hours	5,4	5,5	$5,0^{y}$	5,3	$5,0^{y}$	$4,4^{y}$	$5,2^{x}$	$5,1^{x}$	$5,1^{x}$	$4,3^{y}$	$5,2^{x}$	$4,5^{x}$	$4,7^{xy}$	$7,1^{x}$	$37,6^{y}$	46,7	$43,1^{y}$	$3,7 \times 10^{3}{}_{x}$
Stored frozen 14 days	5,6	5,4	$5,1^{y}$	5,7	$4,8^{z}$	$4,0^{z}$	$4,9^{y}$	$4,8^{y}$	$4,7^{y}$	$4,0^{z}$	$4,8^{y}$	$4,0^{y}$	$4,4^{y}$	$5,8^{y}$	$39,2^{xy}$	48,3	$42,7^{y}$	$2,7 \times 10^{3}{}_{x}$
Significance	NS	NS	***	NS	***	***	*	*	**	***	*	***	**	***	*	NS	**	***

† Each mean average n = 32 (8 panellists x 4 replications)

\# Intensity scale 1 = minimum, 6 = maximum, except for adhesiveness where the scale was reversed

▲ Each mean average of n = 16 (4 per batch x 4 replications)

◆ Fat substitute Simplesse® Dry 100

xyz Mean values in each column block with different superscripts differ significantly regarding storage periods

Cell size and cell distribution showed no significant differences and are not presented in this table

NS Not significant

* $p \leq 0,05$

** $p \leq 0,01$

*** $p \leq 0,001$

Contrary to the results on appearance, storage had a statistically significant effect on almost all the sensory attributes of *texture*. While the full-fat control muffins only differed on compressibility, crumb tenderness and mouthfeel, the experimental muffins with 80% oil replacement differed on most of the textural attributes after frozen storage. Within the full-fat control muffins the texture attributes were retained after ambient storage as in the freshly baked muffins, except for a decrease in crumb tenderness and moistness, while both compressibility and crumb tenderness were decreased and moistness increased after frozen storage. The control muffins did not differ from each other on crumb tenderness after being stored at room and freezer temperatures. This is in contrast to some of the findings of Johnson (1990) who revealed that a similar level of tenderness existed between the freshly baked and frozen-thawed muffins while those stored for 33 h at room temperature were less tender. These differences could be due to differences in the storage conditions (time and temperature) or the fibre content of the muffins since Johnson (1990) reported on muffins with different levels of waxy rice flour and not high-fibre muffins (wheat bran) as in the present study. Within Formula 2, the muffins with partial oil replacement retained most of their original freshly baked texture attributes after being stored for 24 h, namely crust tenderness, crumbliness at initial bite as well as during chewing, adhesiveness and mouthfeel. The crumb was, however, significantly less compressible and less tender after both room and freezer storage than freshly baked. The crumb of the frozen stored muffins was significantly less crumbly and more adhesive and the crust less tender than the freshly baked and the 24 h stored muffins. Within Formula 3, the muffins with total oil replacement also retained their original freshly baked attributes after being stored for 24 h, except for a significant decrease in compressibility and crumb tenderness. The crumb of the 24 h stored muffins were, however, significantly more compressible, tender, crumbly and moist and less adhesive than the frozen stored muffins. This is contrary to the statement of Pence and Standridge (1958) suggesting that firmness changes in frozen cakes (-18 °C) were so small that these might be of lesser concern compared to the higher firmness changes that occurrred after storage at room temperature (21 °C) for the same period (11 days).

Comparing the *flavour* of the muffins within each formula, no significant differences were found between the freshly baked full-fat control muffins and those stored at room or freezer temperatures. Both the experimental muffins were, however, rated significantly

different after freezer storage than freshly baked. The panellists indicated that the sweetness was more perceptible in the frozen-thawed muffins than in the freshly baked muffins with the protein-based fat substitute.

Physical determinations Comparing the Instron results on *compressibility* of the muffins after different periods of storage within each formula, the freshly baked and 24 h stored muffins did not differ significantly from each other for any of the formulas. This was in accordance with the sensory results of the full-fat control muffins but the sensory results on the muffins with partial and total oil replacement indicated that the freshly baked muffins were significantly more compressible than those stored for 24 h. In contrast to the sensory results, the Instron results indicated that the frozen-thawed muffins within all the formulas were more compressible than either of the muffins served without freezing. According to Cauvain and Pateras (1998:11) low gluten systems, such as high-fibre baked products, may have a higher fragility and exhibit a short-term softening effect of the crumb mainly attributed to moisture redistribution within the cake crumb at the initial stages of frozen storage. A gradual softening of the crumb during frozen storage at –20 °C, is caused by the structural distortion which occurs as a result of ice crystal formation and subsequent growth of those crystals during the frozen storage period. Freezing and thawing may also introduce irreversible damage or "stress cracks" in baked products which will lead to easier compression. These results correspond with some of the findings of Johnson (1990) who also revealed that frozen-thawed muffins were more tender than those stored at room temperature, although not different from the freshly baked.

Crust and crumb colour Within each formula the different periods of storage showed no significant differences in crust and crumb colour according to their *lightness (L) values*, except that the freshly baked muffins of Formula 3 showed a lighter crust colour (L) than the 24 h stored muffins, confirming the sensory results. On the contrary, the frozen-thawed muffins of Formula 2 seemed to have a lighter crumb colour than the freshly baked muffins while the sensory results indicated the opposite.

Moisture content Comparing the moisture content of the freshly baked and stored muffins within each formula resulted in only a few significant differences. Within the full-fat control muffins, the moisture content of the freshly baked muffins was retained after

frozen storage but was significantly decreased in the muffins stored at room temperature. Opposite effects occurred in the experimental muffins, while the moisture content of the muffins with partial oil replacement was not affected by storage, those with total replacement were significantly decreased after storage at room and freezer temperature conditions.

Total aerobic mesophilic plate count (AMP) Comparing the total AMP counts of the freshly baked and stored muffins within each formula showed significant differences within the full-fat control muffins and those with total oil replacement. Within the full-fat control muffins the total AMP counts of the 24 h stored muffins was significantly increased compared to the freshly baked muffins, while the frozen stored muffins did not differ significantly from either of them. Although no significant differences were found within the muffins with partial oil replacement, the total AMP counts of those with total oil replacement were significantly increased after storage at both room and freezer temperature conditions compared to the freshly baked muffins.

Correlations between sensory attributes and physical measurements A summary of significant ($p < 0,05$; $r > 0,5$) correlations between sensory attributes and between sensory attributes and physical measures is presented in Table 4. Sensory attributes of appearance correlated significantly with each other but showed either negative or no significant correlations with textural and flavour attributes. All the sensory attributes of appearance, except for crust surface, correlated significantly with physical compressibility and moisture content, indicating that the muffin samples rated high for appearance, contained more moisture and required more force to attain a specific compression. Sensory crust and crumb colour lightness correlated significantly with physical crust and crumb colour lightness respectively, indicating that colour lightness intensity ratings (SE) increased as physical lightness L values increased.

Although sensory ratings for compressibility and crumb tenderness did not correlate significantly with the Instron measurements, significant correlations were obtained between sensory compressibility, crust tenderness, crumbliness and crumb tenderness, indicating that compressibility increased with increased crumbliness and tenderness.

TABLE 4: SIGNIFICANT# CORRELATIONS IN SENSORY ATTRIBUTES AND BETWEEN SENSORY ATTRIBUTES AND PHYSICAL MEASUREMENTS OF HIGH-FIBRE MUFFINS CONTAINING DIFFERENT PERCENTAGES OF SIMPLESSE®

ATTRIBUTES	APPEARANCE					TEXTURE										PHYSICAL			
	Top crust shape	Crust gloss	Crust colour lightness	Crust surface	Crumb colour lightness	Cell distribution	Cell size	Compress-ibility	Crust tenderness	Crumbliness initial bite	Crumbliness after chewing	Crumb tenderness	Adhesiveness	Mouthfeel moistness	FLAVOUR	Compress-ibility Instron	Crust colour (L)	Crumb colour (L)	Moisture
Appearance																			
Top crust shape	-	0,80	0,67	0,56	0,73	NS	NS	NS	-0,57	-0,66	-0,61	NS	0,63	NS	NS	0,60	NS	0,52	0,70
Crust gloss	0,80	-	0,81	0,50	0,87	NS	NS	NS	-0,55	-0,61	-0,61	NS	0,61	NS	NS	0,72	NS	0,57	0,86
Crust colour lightness	0,67	**0,81**	-	NS	**0,98**	NS	NS	NS	-0,71	-0,77	-0,78	-0,50	0,75	NS	NS	0,81	**0,51**	0,73	**0,94**
Crust surface	0,56	0,50	NS	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Crumb colour lightness	0,73	**0,87**	0,98	NS	-	NS	NS	NS	-0,69	-0,74	-0,74	-0,52	0,71	NS	NS	0,83	NS	**0,69**	**0,95**
Texture																			
Cell distribution	NS	NS	NS	NS	NS	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cell size	NS	NS	NS	NS	NS	NS	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Compressibility	NS	NS	NS	NS	NS	NS	NS	-	**0,78**	**0,68**	**0,68**	**0,91**	**-0,63**	NS	0,64	**NS**	NS	-0,62	**NS**
Crust tenderness	-0,57	-0,55	-0,71	NS	-0,69	NS	NS	0,78	-	0,86	0,86	0,83	**-0,86**	NS	0,65	-0,53	-0,50	-0,80	-0,75
Crumbliness initial bite	-0,66	-0,61	-0,66	NS	-0,74	NS	NS	-0,68	0,86	-	0,88	0,77	**-0,90**	NS	0,65	**-0,57**	NS	-0,84	-0,75
Crumbliness after chewing	-0,61	-0,61	-0,78	NS	-0,74	NS	NS	0,68	0,86	0,88	-	0,73	**-0,87**	NS	0,61	**-0,54**	NS	-0,79	-0,76
Crumb tenderness	NS	NS	-0,50	NS	-0,52	NS	NS	**0,91**	0,83	0,77	0,73	-	**-0,69**	NS	0,66	**NS**	NS	-0,77	-0,61
Adhesiveness	0,63	0,61	0,75	NS	0,71	NS	NS	-0,63	-0,86	-0,90	-0,87	-0,69	-	NS	-0,54	**0,50**	NS	0,74	**0,75**
Mouthfeel	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**NS**	-	NS	NS	NS	NS	**NS**
Flavour																			
Typical	NS	NS	NS	NS	NS	NS	NS	0,64	0,65	0,65	0,61	0,66	0,54	NS	-	NS	NS	-0,62	NS
Sweet	NS	NS	NS	NS	NS	NS	NS	-0,68	-0,62	-0,60	NS	-0,68	0,53	NS	**-0,59**	NS	NS	0,57	NS
Nutty	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**NS**	NS	NS	NS	NS
Moisture content	0,70	0,86	**0,94**	NS	**0,95**	NS	NS	NS	-0,75	-0,75	-0,76	**-0,61**	**0,75**	**NS**	NS	**0,82**	NS	0,75	-

#: $p \leq 0,05$; $r > 0,5$
NS = not significant
The correlations printed in bold are discussed in depth in the text

Adhesiveness correlated negatively with compressibility, crust and crumb tenderness and crumbliness, indicating that as adhesiveness increased all these texture attributes were decreased. Significant negative correlations were found between the Instron measurements of compressibility and sensory ratings for crust tenderness and crumbliness, indicating that the higher the force required to attain a specified compression, the lower was the muffins rated for crust tenderness and crumbliness by the sensory panel. Typical flavour correlated negatively with sweet taste indicating that increased sweet taste was related to decreased flavour ratings. Moisture content correlated significantly with sensory ratings of adhesiveness and Instron measurements indicating that adhesiveness and firmness increased with increased moisture content. Moisture content was, however, not related to sensory compressibility, mouthfeel, flavour attributes or total AMP counts and negatively related to crust and crumb tenderness as well as crumbliness. Muffins with higher moisture content were rated lower for these textural attributes. No significant correlations were found for the attributes of cell distribution, cell size, mouthfeel, nutty taste and total AMP counts.

Cluster analysis Taking a maximum Euclidian distance between two types to be one unit in order to establish similarity of types, the full-fat control, with its combinations of different storage periods, fell into one cluster with the other two formulas and their combinations into a second cluster. This means that the full-fat control was evaluated similarly for all the sensory as well as physical attributes considered, but differently from the two experimental formulas with Simplesse®.

CONCLUSION

This study revealed that oil replacement was the major source of significant variation, while storage period and temperature showed significant variation to a minor extent. The use of Simplesse® Dry 100 seemed to enhance the attributes of appearance, and maintain the flavour and some of the textural attributes of low-fat high-fibre muffins, while most of the textural attributes were adversely affected. Although the results demonstrated that textural attributes provided by oil are difficult to achieve with oil replacement, the mean ratings of the muffins with Simplesse® indicated maintained quality close to that of the full-fat control, even after storage.

When focusing on the effects of storage within each formula it can be concluded that the muffins with partial oil replacement showed fewer attribute changes after 24 h storage than the full-fat control and muffins with total oil replacement. Although no significant differences exist in the moisture content of the muffins with partial oil replacement within the different storage periods, the frozen-thawed experimental muffins were perceived as less crumbly and moist but more adhesive than the 24 h stored. These observations and the anti-firming effect of increased protein of the experimental muffins with protein-based fat substitute could possibly be responsible for the lessened staling effects during short-term storage at room temperature. This finding on the effect of 24 h storage on high-fibre muffins containing different levels of Simplesse®, is new and has important applications in food service.

Regarding frozen storage of the three muffin variations, fewer attribute changes occurred in the frozen stored control muffins than those stored for 24 h. The freeze stability of these full-fat control muffins illustrates the well-known fact in the baking industry that high-fat baked products freeze better than low-fat products. More attribute changes occurred, however, in the muffins with 80% oil replacement due to frozen storage than during 24 h storage at room temperature, and also more than in the other two formulas after frozen storage. These results lead to the conclusion that the function of oil in preventing changes during frozen storage is not fully replaced by Simplesse® in muffins with partial oil replacement. It seems, however, that the muffins with total oil replacement were more resistant to changes during frozen storage and differed on fewer attributes from the muffins with partial oil replacement after frozen storage than when both were freshly baked or stored for 24 h at room temperature.

Possible reasons for the slightly more adverse effects during frozen storage, additional to the effect of reduced-fat content, could possibly be due to the initial slow freezing process and slow thawing process combined with the higher moisture content of the experimental muffins which could provide ample opportunity for moisture migration and staling during frozen storage and thawing. Note, however, that these contrary effects of frozen storage can not be accounted for and explained without specific physical measurements being conducted to assess whether any changes in starch crystallinity or moisture migration to equilibration levels etc. occurred in the product.

The conclusion that muffins with partial as well as total oil replacement with Simplesse® can be stored at room temperature without remarkable adverse effects, but cannot be frozen as successfully, especially the partial replacement formula, makes an unique contribution to knowledge regarding storage of baked products with oil replacement. It can thus be recommended that partial and total oil replacement can be used when storage at room temperature is intended, but not when frozen storage is required, although it is recommended that other temperatures for freezing (-12 to –18 °C) should also be examined.

The findings of this study emphasise the possibilities of fat substitution in developing a low-fat, high-fibre product with good eating quality and storage stability. With the emphasis on reducing fat and increasing fibre intake to reduce the risk of diet-related diseases, these low-fat, high-fibre muffins with Simplesse® would be an important contribution to energy-reduced, fibre-enriched convenient foods.

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CHAPTER 6

THE EFFECT OF BATTER REFRIGERATION ON THE CHARACTERISTICS OF HIGH-FIBRE MUFFINS WITH DIFFERENT LEVELS OF OIL REPLACEMENT WITH A PROTEIN-BASED FAT SUBSTITUTE

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OPSOMMING

As deel van 'n sistematiese proses in die ontwikkeling van 'n laevet- hoëveselmuffin, word die invloed van olievervanging en verkoeling van die beslag op die kwaliteitseienskappe van die muffins gerapporteer. Bykomend tot die toenemende vraag na laevet, hoëveselprodukte in 'n poging om vetinname en dus risiko vir chroniese siektes te verlaag, plaas die verbruiker al groter klem op die beskikbaarheid van varsgebakte produkte. Vinnige broodjies soos muffins, wat van voorafbereide, verkoelde beslag vars gebak word, kan help om aan hierdie behoeftes te voldoen. Daar is egter min bekend oor die invloed van verkoeling van enige laevet- hoëveselbeslag op die kwaliteitseienskappe en mikrobiologiese tellings van die varsgebakte produk.

Die doel van hierdie studie was dus om die sintuiglike en fisiese eienskappe van hoëveselmuffins wat vars gebak is van beslag wat óf vars berei is óf vir 24 en 48 uur onderskeidelik verkoel is, te vergelyk. Die eienskappe van muffins waarin geen (kontrole), 80% of 100% van die olie met Simplesse®, 'n proteïengebaseerde vetvervanger vervang is, is ondersoek. Bykomend is mikrobiologiese toetse (aerobiese mesofiele bakterietellings, asook giste en skimmels) op die gebakte produk gedoen.

'n Onvolledige, gebalanseerde blokontwerp met twee faktore is gebruik, naamlik die vlak van olievervanging (geen, 80 en 100%) en drie periodes van beslagverkoeling (geen, 24 en 48 uur). Die muffinbeslag is berei soos gerapporteer (Bosman *et al*, 1996:50). Beslag wat nie verkoel is nie (zero-verkoelingstyd) is direk na hidratering gebak. Die verkoelde beslag is by 0-4 °C vir 24 en 48 uur gestoor en vir 60 min by kamertemperatuur gehou voordat dit gebak is. Sintuiglike evaluering en fisiese bepalings op die varsgebakte produk is gedoen met metodes soos reeds beskryf (Bosman *et al*, 1996:50; Bosman *et al*, 1998, manuskrip voorgelê). Mikrobiologiese tellings is met die SABS metode 756 en ISO metode 7954

uitgevoer. Twee- en eenrigting variansie-analises met Tukey se meervoudige vergelykende toetse is gebruik om die statisties-betekenisvolheid van die effek van olievervanging en verkoeling van die beslag op alle gemete veranderlikes te bepaal. Die verwantskap tussen sintuiglike en fisiese veranderlikes is met Pearson produk-moment korrelasies getoets en trosanalises (met Euclidiese afstande) is gebruik om ooreenkomste tussen die veranderlikes te meet.

Die resultate het getoon dat, alhoewel beide olievervanging en verkoeling van die beslag byna al die sintuiglike en fisiese eienskappe van muffins betekenisvol beïnvloed het, die omvang van die verskille relatief klein was en dat al die muffins ten spyte van olievervanging of verkoeling van die beslag, hoë tellings vir al die veranderlikes verkry het. Geen verskille in die mikrobiologiese tellings is waargeneem nie. Die gemiddelde totale tellings van die mesofiele aerobe bakterieë ($5,0x10^2$ - $6,3x10^2$ CFU/g) was laer as die toelaatbare aanbevole kriteria. Geen giste of skimmels is in enige van die muffins waargeneem nie.

Die omvang van verskille as gevolg van olievervanging op die sintuiglike en fisiese eienskappe van voorkoms, tekstuur, smaak, volume en hoogte, voginhoud en die persentasie vogverlies tydens die bakproses, was oor die algemeen groter as die effek van verkoeling van die beslag vir 24 of 48 uur voor die bakproses op die meeste van hierdie veranderlikes. Wanneer die effek van beslagouderdom binne elke formule vergelyk word, het dit duidelik geblyk dat meer van die eienskappe van die kontrole muffins deur verkoelde opberging van die beslag beïnvloed is as van die eksperimentele muffins. Dit dui daarop dat Simplesse® waarskynlik die stabiliteit van die muffinbeslag verhoog het sodat dit minder as die kontrole muffins tydens verkoelingsperiodes van 24 en 48 uur voor die bakproses, verander het. Beide die kontrole en eksperimentele muffins wat van koelopgebergde beslag gebak is, was oor die algemeen effens donkerder, fermer, minder krummelrig en kleiner in volume en hoogte as dié van varsbereide beslag. Hierdie resultate, tesame met die lae bakterietellings, dui daarop dat waar nodig, die laevet- hoëveselmuffinbeslag met Simplesse® vir periodes van 24 of 48 uur by 0-4 °C met veiligheid verkoel kan word voordat dit gebak word om steeds 'n produk van hoë kwaliteit te lewer.

INTRODUCTION

The availability of low-fat products could contribute to lower fat intake of a population aiming to lower risk of chronic diseases of lifestyle. A low-fat, high-fibre muffin containing various levels of fat substitute, was developed in our laboratory. The characteristics of these muffins (Bosman *et al*, 1996), dietitians' attitudes towards fat substitutes and acceptability of the low-fat high-fibre muffins (Bosman *et al*, 1997a), consumer acceptance (Bosman *et al*, 1997b) as well as the effects of oil replacement and storage on quality characteristics (Bosman *et al*, submitted) were systematically examined. In this contribution we report on the effect of batter refrigeration on the quality characteristics of muffins with different percentages of oil replacement.

In addition to the growing demand for low-fat, high-fibre products, consumers are placing even greater importance on freshness. In fact, Food Technology's "Top Ten Trends to Watch and Work On" cites *freshness* as the second most important food industry trend (Sloan, 1994:89). According to the Health Focus Survey of US consumers, *fresh* tops the list of the most desirable label claim (57%) with *fat free* a distant second (Faridi, 1995:7). In response to the consumer's quest for fresh food, scientists and food service operations are searching for innovative ways to offer nutritious, fresh products in a cost and time effective way (Gibson, 1995:16). Freshly baked products such as bread and muffins have special appeal for consumers in search for nutrition and flavour. Consumer needs for foods that are convenient, high-quality and healthy, can be partially served by refrigerated batters for quick breads, such as muffins (Dorko & Penfield, 1993:574). However, published research on refrigerated batters and the effect of high-fibre content, oil replacement and batter refrigeration on freshly baked product quality is limited. Moreover, little is known about the microbiological safety of these products. The chief microbiological concern associated with extended shelf life served by refrigerated batters, centers on mesophilic and psychrotrophic micro-organisms such as yeasts and moulds that could grow during extended refrigerated storage or temperature abuse (Marth, 1998:57).

According to Dorko and Penfield (1993:575-578) the moisture content and shape of bran muffins baked from refrigerated batters was not affected by batter storage while the muffin crumb became darker, less crumbly, although easier to chew as batter storage time increased. Quinn (1995:56) reported on declining height and tunneling of baked muffins after batter

refrigeration in previous studies done at a hospital changing from a conventional food service system to a cook-chill system. Presoaking the cereal bran and adding the flour during the last step of mixing, appeared to improve the texture of these muffins. Baking muffins at higher temperatures contributed to higher baked heights although the heights of muffins baked from refrigerated batters decreased as storage time increased.

Information on the effect of refrigeration on the quality of high-fibre muffins in which the oil was replaced, could thus be important in food services. If the batter could be prepared during a slack period one or two days ahead and freshly baked when needed, without adverse effects on quality, it could contribute to more efficient use of employee time and equipment in producing a fresh baked product.

OBJECTIVE

The objective of this study was to evaluate the effect of batter refrigeration on the sensory and physical characteristics and microbiological counts of high-fibre muffins with different percentages of oil replacement. Muffins freshly baked from either freshly prepared batter or batter refrigerated for 24 h or 48 h respectively, were also compared within each formula.

MATERIALS AND METHODS

Experimental design

High-fibre muffins with zero, 80% and 100% oil replacement with Simplesse® Dry 100 baked from freshly prepared and refrigerated batters were studied. The experiment was an incomplete balanced-block design with two factors: three levels of oil replacement (zero, 80 and 100%) and three periods of batter refrigeration (freshly prepared (zero), 24 h and 48 h refrigerated, respectively) with four replications as shown in Figure 1.

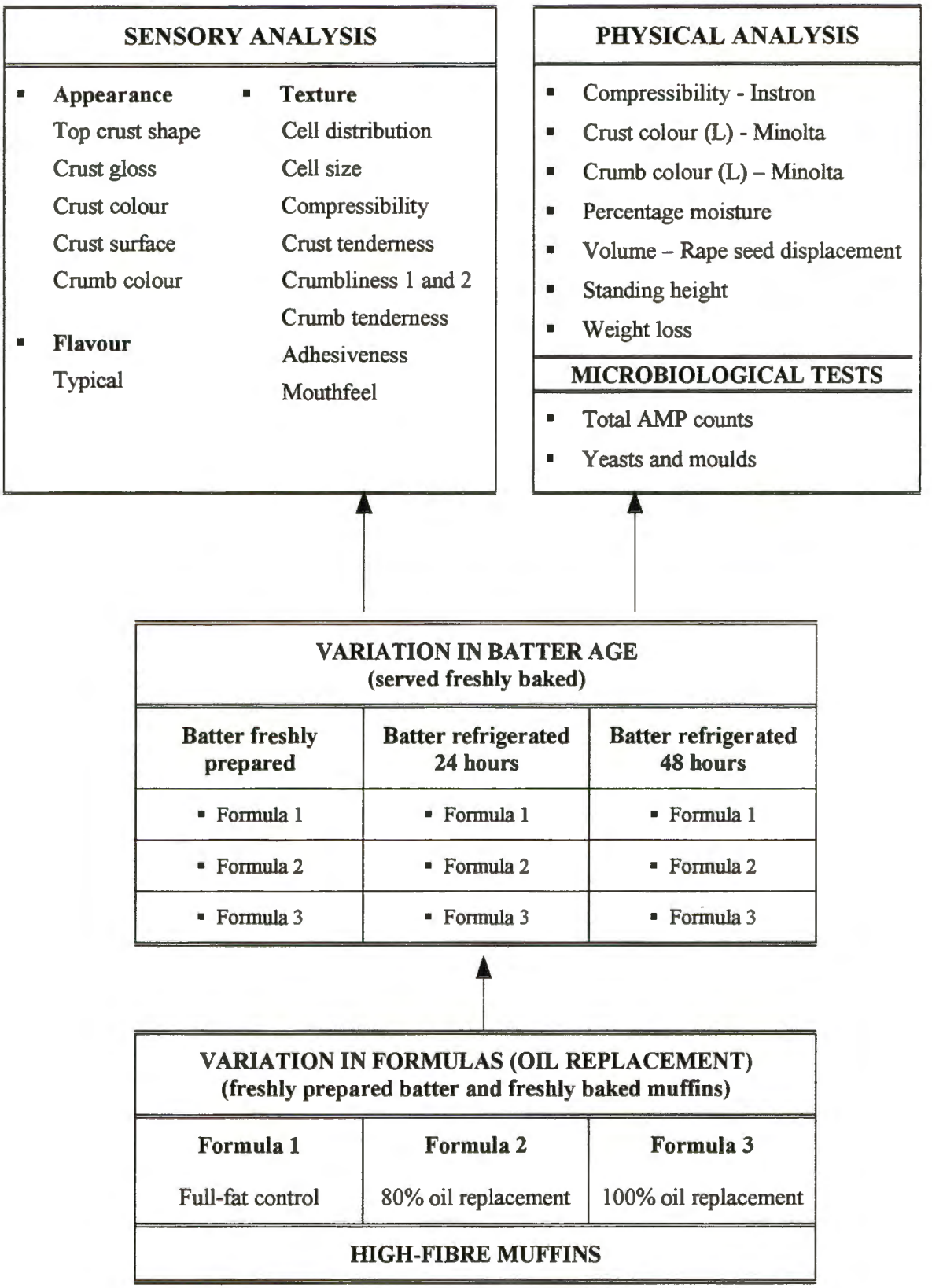

FIGURE 1: EXPERIMENTAL DESIGN – The effect of oil replacement and batter refrigeration on the characteristics of high-fibre muffins

Muffin formulations and preparation

Batters of high-fibre muffins with zero, 80% and 100% oil replacement with Simplesse® (full-fat control Formula 1, Formula 2 and formula 3, respectively) were freshly prepared as described by Bosman *et al* (1996:50). The batters were mixed only until well moistened but still lumpy (20 strokes) and were immediately poured into one litre plastic buckets with tight sealing lids and left at room temperature to hydrate for 1 h. The buckets were coded according to the formulas and the three periods of batter refrigeration. Batter samples to be baked freshly prepared (zero-time refrigeration) were scooped and weighed (70 g) into each cup of a standard 12 count aluminium muffin pan, sprayed with non-stick spray immediately after hydration. Those to be baked from refrigerated batters were stored in a refrigerator at 0-4 °C for 24 h and 48 h respectively. The refrigerated batter was held at room temperature for 1 h before samples were scooped into the pans for baking. Muffins were baked, cooled and packaged at the end of each batter refrigeration period as described previously (Bosman *et al.* 1996:50). All baked samples were stored in plastic bags at room temperature for only 1 h until the sensory and physical measurements were conducted.

Sensory analysis

Sensory analysis was conducted by an analytical descriptive panel selected and trained as described by Bosman *et al* (1996). The sensory evaluation of the muffins was performed according to the sensory attributes defined and scale anchors set by the panel as described by Bosman *et al* (1998 - submitted). A six-point Likert-type rating scale, where 1 represents the minimum and 6 the maximum intensity of each attribute, was used. Evaluations were conducted under controlled conditions in partitioned booths in 10 sessions over a 5-week period. Two series of three samples each (one sample per formula) were presented individually on small white coded plates on a white tray. Water at room temperature was provided for mouth rinsing before and between each of the three samples in a series. Apple slices were served in the 10 min break between the two series of each session.

Physical determinations

Additional physical determinations other than lightness of crust and crumb colour (L values), compressibility and moisture content as described in the previous study (Bosman *et al*,

1998:submitted), namely standard height, volume and percentage moisture loss during baking, were also done. The standard height of eight muffins from each batch was measured at the centre of each muffin, while the volume of each group of eight muffins was determined by rapeseed displacement. Percentage moisture loss during baking was calculated from the mass before and after the baking of eight muffins from each batch.

Microbiological counts

The following counts were done in duplicate on each sample of baked muffins collected per session: total aerobic mesophilic plate count (AMP) of viable bacteria as well as yeasts and moulds. The tests were done according to the Standard Methods of the SA Bureau of Standards (SABS), namely SABS Method 756 and ISO Method 7954 respectively. The microbial counts were reported as colony forming units per gram (CFU/g)

Statistical analyses

Two-way and one-way analyses of variance (ANOVA) and Tukey's multiple comparison tests ($p<0,05$) were applied to the sensory, physical and microbiological data to determine whether the muffins from the different formulas differed significantly within each of the batter refrigeration periods or within each formula at the different batter refrigeration periods. The relationship among the sensory and physical variables was analysed by means of Pearson's product-moment correlations. Cluster analysis was performed separately on the sensory and physical data by linking the types by the average linkage method using the Euclidian distances between the types. The SAS Institute, Inc. (1988) programme was used for data analyses.

RESULTS AND DISCUSSION

Analysis of variance of the sensory and physical results summarised in Tables 1 to 4, respectively, revealed that both independent variables, namely oil replacement and batter refrigeration had significant effects on almost all the characteristics measured in this study. No differences in microbiological counts were observed. The mean total counts of the mesophilic aerobic bacteria varied between $5,0 \times 10^2$ and $6,3 \times 10^2$ CFU/g, which are substantially lower than the advisory criteria and falls within the microbiological profile of

baked products that are in the range of $10\text{-}10^3$ CFU/g (Elliot, 1980:696), indicating good bacterial quality for all the muffin variations. No counts of yeast and moulds were detected in any of the samples analysed, even after refrigerated storage (4-5 °C) of the baked muffins for seven days irrespective of oil replacement or batter age. Since the bacterial counts were not affected by either oil replacement or batter refrigeration, these were deleted from Tables 2 and 4.

*** Effect of oil replacement on sensory and physical characteristics of high-fibre muffins within each period of batter refrigeration (age)**

According to the results, oil replacement had a statistically significant effect ($p<0,05$) on all the sensory and physical characteristics of the muffins except cell distribution, cell size and the total count of aerobic mesophilic bacteria as determined within each of the different periods of batter refrigeration, namely freshly prepared (zero), refrigerated for 24 h or 48 h, respectively.

Comparing the muffins with different levels of oil replacement (Simplesse®) baked from freshly prepared batter, both the experimental muffins, although not significantly different for mouthfeel or flavour, showed significantly higher mean values for the sensory and physical attributes of appearance, volume, height and moisture content and significantly lower means for most of the textural attributes than the full-fat control muffins. These findings confirmed the statement by Armbrister and Setser (1994:350), *viz.* that the textural attributes such as tenderness, moist mouthfeel and lubricity provided by fat in baked products are difficult to achieve with fat substitutes.

Comparing the characteristics of the muffins baked from freshly prepared batter, the muffins with Simplesse® exhibited a more symmetrical, slightly rounded crust shape, a glossier, lighter brown crust and crumb colour, a more pebbled and coarse crust surface, but a less compressible, less crumbly, less tender and more adhesive crumb than the full-fat control muffins. Fulton and Hogbin (1993:1315) also reported on decreased muffin tenderness as fat levels decreased. The present results correspond with some of Armbrister and Setser's findings (1994:347), indicating that chocolate chip cookies made with Simplesse® Dry 100 were also less crumbly and slightly more cohesive. However, the results differed from their findings in that surface roughness decreased and cell size and crumb tenderness increased with increased oil replacement.

TABLE 1: MEAN VALUES† FOR THE SENSORY CHARACTERISTICS OF HIGH-FIBRE MUFFINS WITH DIFFERENT LEVELS OF OIL REPLACEMENT COMPARED AT THREE DIFFERENT BATTER AGES AND SERVED FRESHLY BAKED

	APPEARANCE					TEXTURE									FLAVOUR
	Top crust shape	Crust gloss	Crust colour lightness	Crust surface	Crumb colour lightness	Cell distribution	Cell size	Compressibility	Crust tenderness	Crumbliness initial bite	Crumbliness after chewing	Crumb tenderness	Adhesiveness	Mouthfeel Moistness	
Significance (2 x ANOVA)															
Formula (F)	***	***	***	***	***	NS	NS	*	***	***	***	***	***	***	***
Batter age (B)	**	***	***	NS	***	***	***	***	***	***	***	***	**	***	***
B x F	NS	NS	**	NS	NS	NS	NS	NS	NS	***	NS	NS	NS	*	NS
Muffins - Batter freshly prepared															
100% oil (control)	$4,9^{b}$	$4,8^{c}$	$4,0^{c}$	$4,9^{b}$	$4,0^{c}$	$5,3^{a}$	$5,3^{a}$	$5,4^{a}$	$6,0^{a}$	$5,9^{a}$	$5,8^{a}$	$5,8^{a}$	$5,8^{a}$	$4,3^{a}$	$5,3^{a}$
80% oil replacement◆	$5,8^{a}$	$5,9^{a}$	$4,9^{b}$	$5,7^{a}$	$4,9^{b}$	$5,6^{a}$	$5,6^{a}$	$5,0^{ab}$	$5,8^{b}$	$5,5^{b}$	$5,2^{b}$	$5,2^{b}$	$5,4^{b}$	$4,5^{a}$	$5,3^{a}$
100% oil replacement	$5,6^{a}$	$5,5^{b}$	$5,5^{a}$	$5,4^{a}$	$5,2^{a}$	$5,3^{a}$	$5,4^{a}$	$4,8^{b}$	$5,1^{c}$	$5,0^{c}$	$4,9^{c}$	$5,0^{b}$	$4,9^{c}$	$4,5^{a}$	$5,0^{a}$
Significance	***	***	***	***	***	NS	NS	**	***	***	***	***	***	NS	NS
Muffins - Batter refrigerated 24 hours															
100% oil (control)	$5,2^{a}$	$4,5^{b}$	$3,5^{c}$	$5,1^{a}$	$3,6^{b}$	$5,3^{a}$	$5,2^{a}$	$4,9^{a}$	$5,7^{a}$	$5,3^{a}$	$5,7^{a}$	$5,4^{a}$	$5,4^{a}$	$4,4^{a}$	$5,5^{a}$
80% oil replacement	$5,6^{a}$	$5,4^{a}$	$4,5^{b}$	$5,4^{a}$	$4,6^{a}$	$5,1^{a}$	$5,3^{a}$	$4,8^{a}$	$5,5^{a}$	$5,2^{a}$	$5,1^{b}$	$5,1^{a}$	$5,3^{a}$	$4,5^{a}$	$5,3^{a}$
100% oil replacement	$5,4^{a}$	$5,2^{a}$	$5,3^{a}$	$5,2^{a}$	$4,7^{a}$	$5,2^{a}$	$5,1^{a}$	$4,7^{a}$	$4,8^{b}$	$4,8^{b}$	$4,6^{c}$	$4,7^{b}$	$5,0^{b}$	$4,5^{a}$	$4,8^{b}$
Significance	NS	***	***	NS	***	NS	NS	NS	***	***	***	***	***	NS	***
Muffins - Batter refrigerated 48 hours															
100% oil (control)	$4,7^{b}$	$4,5^{c}$	$3,9^{c}$	$4,7^{b}$	$3,8^{b}$	$4,8^{a}$	$4,8^{a}$	$4,6^{a}$	$5,7^{a}$	$4,2^{c}$	$5,4^{a}$	$5,1^{a}$	$5,4^{a}$	$3,9^{b}$	$4,8^{a}$
80% oil replacement	$5,3^{a}$	$5,6^{a}$	$4,8^{b}$	$5,4^{a}$	$4,7^{a}$	$5,1^{a}$	$5,1^{a}$	$4,7^{a}$	$5,2^{b}$	$5,0^{a}$	$4,9^{b}$	$4,8^{ab}$	$5,2^{a}$	$4,4^{a}$	$4,9^{a}$
100% oil replacement	$5,4^{a}$	$5,2^{b}$	$5,1^{a}$	$5,4^{a}$	$4,8^{a}$	$5,1^{a}$	$5,0^{a}$	$4,5^{a}$	$4,8^{b}$	$4,6^{b}$	$4,7^{b}$	$4,3^{b}$	$4,8^{b}$	$4,5^{a}$	$4,6^{a}$
Significance	**	***	***	***	***	NS	NS	NS	***	***	***	**	***	***	NS

† Intensity scale 1 = minimum; 6 = maximum, except for adhesiveness where the scale was reversed
Each mean average of n = 32 (8 panellists x 4 replications)

◆ Protein-based fat substitute: Simplesse® Dry 100

abc Mean values with different superscripts in each column block, differ significantly regarding formula

NS Not significant
* $p \leq 0,05$
** $p \leq 0,01$
*** $p \leq 0,001$

Appearance Comparing the muffins of the different formulas baked from 24 h refrigerated batters on appearance showed a different tendency of differences than among the muffins baked from freshly prepared batters. Contrary to the results with freshly prepared batter, the full-fat control and experimental muffins baked from 24 h refrigerated batter did not differ significantly for top crust shape and surface, showing a symmetrical, slightly rounded crust shape and a pebbled coarse surface. However, the experimental muffins baked from 24 h refrigerated batter differed significantly from the the full-fat control muffins for having a glossier crust and a lighter crust and crumb colour. These significant differences in crust and crumb colour lightness between the experimental and full-fat muffins were confirmed by the instrumental results (Table 2). The same tendency of differences in appearance as in the freshly prepared batters, was observed, however, among the muffins of the different formulas baked from 48 h refrigerated batters. The experimental muffins baked from 48 h refrigerated batters were also rated significantly higher than the full-fat control muffins on all the attributes of appearance as in the case of the muffins baked from freshly prepared batter. The experimental muffins baked from 48 h refrigerated batter did not differ significantly from each other for top crust shape, crust surface or crumb colour lightness.

Texture Contrary to the results of the freshly prepared batters, the control muffins baked from 24 h refrigerated batters did not differ significantly from the muffins with 80% oil replacement in any of the textural attributes except for being more crumbly after chewing. Although not significantly different for compressibility and mouthfeel, the muffins with total oil replacement baked from 24 h refrigerated batter differed significantly in the other textural attributes by being less tender, less crumbly and more adhesive than the full-fat muffins and those with partial oil replacement. Contrary to the sensory results that showed no significant differences among the muffins of the different formulas, baked from either 24 h or 48 h refrigerated batters, the Instron results indicated that the full-fat control muffins were significantly more compressible than both experimental muffins baked from 24 h and 48 h refrigerated batters respectively. The crust of the control muffins was more tender and the crumb more crumbly after chewing, while less crumbly at initial bite and less moist than the experimental muffins with 80% and 100% oil replacement. While the full-fat control and muffins with 80% oil replacement did not differ significantly in crumb tenderness and adhesiveness, the crumb of the muffins with total oil replacement was significantly less tender than the crumb of the full-fat control muffins and more adhesive than both the control

and those with 80% oil replacement.

Flavour While the flavour of the full-fat control muffins did not differ significantly from the experimental muffins baked from either freshly prepared or 48 h refrigerated batters, the muffins with total oil replacement baked from 24 h refrigerated batter, were perceived as significantly less typical in flavour than the full-fat control muffins and those with 80% oil replacement.

Volume and height The experimental muffins with additional protein (Simplesse®) and oil replacement exhibited increased volume and height compared to the full-fat control muffins, baked from either freshly prepared or refrigerated batters. Results obtained by Cauvain (1991:83) also indicated increased cake volume with decreased fat levels and increased protein levels when skimmed milk powder was used. The finding of the present study, namely that the height of the muffins increased with decreased levels of oil, was contrary to the results of Fulton and Hogbin (1993:1316) who found that the height of cakes was not affected by reduced fat levels.

Percentage weight loss during baking Although no significant differences in percentage weight loss during baking occurred between the full-fat control and the muffins with oil replacement baked from either freshly prepared or 48 h refrigerated batters, the full-fat control muffins baked from 24 h refrigerated batter showed significantly lower weight losses than the muffins with 100% oil replacement. This confirms the findings of Hogbin and Fulton (1992:995) and Conforti *et al* (1996:289), *viz.* that moisture loss in baked products tended to increase as the level of fat decreased.

Moisture content The moisture content of the experimental muffins with Simplesse® was significantly higher than that of the full-fat control muffins baked from either freshly prepared or 48 h refrigerated batters. Although not significantly different when baked from freshly prepared or 48 h refrigerated batter, the experimental muffins differed significantly from each other when baked from 24 h refrigerated batter. This confirms the findings of Conforti *et al* (1996:289) that moisture content increased significantly in biscuits with increased use of carbohydrate-based fat substitutes. In contrast to the findings of Cauvain (1991:83) the muffins with Simplesse® showed increased volume with increased moisture level.

TABLE 2: MEAN VALUES▲ FOR THE PHYSICAL CHARACTERISTICS OF HIGH-FIBRE MUFFINS WITH DIFFERENT LEVELS OF OIL REPLACEMENT COMPARED AT THREE DIFFERENT BATTER AGES AND SERVED FRESHLY BAKED

	Compress-ibility (N)	Crust colour (L)	Crumb colour (L)	Volume (ml)	Height (mm)	Weight loss (%)	Moisture (%)
Significance (2 x ANOVA)							
Formula (F)	***	***	***	***	***	***	***
Batter age (B)	NS	***	***	***	***	***	**
B x F	NS	NS	NS	***	***	NS	NS
Muffins - Batter freshly prepared							
100% oil (control)	$5,0^{c}$	$35,2^{b}$	$40,0^{c}$	$912,6^{b}$	$40,3^{c}$	$13,2^{a}$	$38,2^{b}$
80% oil replacement◆	$6,3^{b}$	$37,6^{ab}$	$42,6^{b}$	$993,3^{a}$	$43,3^{b}$	$13,7^{a}$	$42,4^{a}$
100% oil replacement	$7,0^{a}$	$40,9^{a}$	$46,6^{a}$	$1003,9^{a}$	$44,3^{a}$	$13,9^{a}$	$44,1^{a}$
Significance	***	**	***	***	***	NS	***
Muffins - Batter refrigerated 24 hours							
100% oil (control)	$5,4^{b}$	$37,3^{b}$	$41,0^{c}$	$859,8^{b}$	$37,8^{b}$	$11,9^{b}$	$37,3^{c}$
80% oil replacement	$6,8^{a}$	$40,5^{a}$	$45,5^{b}$	$973,8^{a}$	$43,2^{a}$	$12,7^{ab}$	$42,0^{b}$
100% oil replacement	$7,3^{a}$	$42,5^{a}$	$49,6^{a}$	$982,2^{a}$	$42,4^{a}$	$13,2^{a}$	$43,3^{a}$
Significance	***	***	***	***	***	***	***
Muffins - Batter refrigerated 48 hours							
100% oil (control)	$5,5^{b}$	$34,9^{b}$	$40,3^{c}$	$823,4^{c}$	$36,3^{c}$	$11,1^{a}$	$37,4^{b}$
80% oil replacement	$6,4^{a}$	$37,5^{b}$	$43,8^{b}$	$951,7^{b}$	$41,9^{b}$	$11,0^{a}$	$42,3^{a}$
100% oil replacement	$6,9^{a}$	$40,7^{a}$	$46,7^{a}$	$968,2^{a}$	$42,8^{a}$	$11,5^{a}$	$42,5^{a}$
Significance	***	***	***	***	***	NS	***

▲ Each mean is the average of values obtained from n = 16 (4 per batch x 4 replications)

◆ Protein-based fat substitute: Simplesse® Dry 100

abc Mean values with different superscipts in each column block, differ significantly regarding formula

NS Not significant

* $p \leq 0,05$

** $p \leq 0,01$

*** $p \leq 0,001$

*** Effect of batter refrigeration on the sensory and physical characteristics of the muffins within each formula**

According to the results provided in Tables 3 and 4, batter refrigeration had a statistically significant effect ($p<0,01$) on all the sensory and physical characteristics of the muffins, except for crust surface, compressibility (Instron Universal Testing Machine) and the total aerobic mesophilic plate counts (AMP) within all the formulas as compared to the muffins baked from freshly prepared batter.

Appearance Comparing the muffins baked from freshly prepared and refrigerated batter within each formula on appearance showed only very few significant differences within the full-fat control muffins. Top crust shape, crust gloss and crust surface were not significantly affected by batter refrigeration while the crust and crumb colour became darker with batter storage. Although these results were not confirmed by the instrumentally-obtained lightness (L) values, they are in agreement with the findings of Dorko and Penfield (1993:581) who also indicated darkening of the crumb with batter storage.

In the case of the muffins with partial oil replacement, batter refrigeration affected more attributes of appearance. The muffins baked from 24 h refrigerated batter showed a significantly less glossy, darker crust and crumb colour than those baked from freshly prepared batter. The muffins baked from 48 h refrigerated batter differed, however, only for having a less even top crust shape and a less glossy crust than those baked from freshly prepared batter. These sensory results on crust and crumb colour were, however, not confirmed by the instrumental results. On the contrary, batter refrigeration of 24 h only affected the crumb colour while 48 h refrigeration affected both crust and crumb colour of the muffins with total oil replacement also showing a darkening effect.

Texture Contrary to the results on appearance, batter refrigeration had a statistically significant effect on all the sensory attributes of texture within the full-fat control muffins while only a few attributes within the muffins with partial oil replacement and even fewer within the muffins with total oil replacement were significantly affected.

TABLE 3: MEAN VALUES† FOR THE SENSORY CHARACTERISTICS OF HIGH-FIBRE MUFFINS OF 3 FORMULAS WITHIN DIFFERENT BATTER AGES AND SERVED FRESHLY BAKED

	APPEARANCE					TEXTURE									FLAVOUR
	Top crust shape	Crust gloss	Crust colour lightness	Crust surface	Crumb colour lightness	Cell distribution	Cell size	Compressibility	Crust tenderness	Crumbliness initial bite	Crumbliness after chewing	Crumb tenderness	Adhesiveness	Mouthfeel Moistness	
Formula 1: Full-fat control															
Batter freshly prepared	4,9	4,8	$4,0^{x}$	4,9	$4,0^{x}$	$5,3^{x}$	$5,3^{x}$	$5,4^{x}$	$6,0^{x}$	$5,9^{x}$	$5,8^{x}$	$5,8^{x}$	$5,8^{x}$	$4,3^{x}$	$5,3^{x}$
Batter refrigerated 24 h	5,2	4,5	$3,5^{y}$	5,1	$3,6^{y}$	$5,3^{x}$	$5,2^{xy}$	$4,9^{y}$	$5,7^{y}$	$5,3^{y}$	$5,7^{xy}$	$5,4^{y}$	$5,4^{y}$	$4,4^{x}$	$5,5^{x}$
Batter refrigerated 48 h	4,7	4,5	$3,9^{x}$	4,7	$3,8^{y}$	$4,8^{y}$	$4,8^{y}$	$4,6^{y}$	$5,7^{y}$	$4,2^{z}$	$5,4^{y}$	$5,1^{y}$	$5,4^{y}$	$3,9^{y}$	$4,8^{y}$
Significance	NS	NS	***	NS	***	*	*	***	**	***	*	***	*	***	**
Formula 2: 80% oil replacement◆															
Batter freshly prepared	$5,8^{x}$	$5,9^{x}$	$4,9^{x}$	5,7	$4,9^{x}$	$5,6^{x}$	$5,6^{x}$	5,0	$5,8^{x}$	$5,5^{x}$	$5,2^{x}$	5,2	5,4	4,5	$5,3^{x}$
Batter refrigerated 24 h	$5,6^{xy}$	$5,4^{y}$	$4,5^{y}$	5,4	$4,6^{y}$	$5,1^{y}$	$5,3^{xy}$	4,8	$5,5^{x}$	$5,2^{y}$	$5,1^{xy}$	5,1	5,3	4,5	$5,3^{x}$
Batter refrigerated 48 h	$5,3^{y}$	$5,6^{y}$	$4,8^{x}$	5,4	$4,7^{xy}$	$5,1^{y}$	$5,1^{y}$	4,7	$5,2^{y}$	$5,0^{y}$	$4,9^{y}$	4,8	5,2	4,4	$4,9^{y}$
Significance	*	***	***	NS	**	**	*	NS	***	***	*	NS	NS	NS	*
Formula 3: 100% oil replacement															
Batter freshly prepared	5,6	5,5	$5,5^{x}$	5,4	$5,2^{x}$	5,3	5,4	4,8	5,1	$5,0^{x}$	$4,9^{x}$	$5,0^{x}$	4,9	4,5	5,0
Batter refrigerated 24 h	5,4	5,2	$5,3^{xy}$	5,2	$4,7^{y}$	5,2	5,1	4,7	4,8	$4,8^{xy}$	$4,6^{y}$	$4,7^{xy}$	5,0	4,5	4,8
Batter refrigerated 48 h	5,4	5,2	$5,1^{y}$	5,4	$4,8^{y}$	5,1	5,0	4,5	4,8	$4,6^{y}$	$4,7^{xy}$	$4,3^{y}$	4,8	4,5	4,6
Significance	NS	NS	**	NS	***	NS	NS	NS	NS	*	*	***	NS	NS	NS

† Intensity scale 1 = minimum, 6 = maximum, except for adhesiveness where the scale was reversed
Each mean average of n = 32 (8 panellists x 4 replications)

◆ Protein-based fat substitute: Simplesse® Dry 100

xyz Mean values with different superscripts in each column block, differ significantly regarding batter age

NS Not significant
* $p \leq 0,05$
** $p \leq 0,01$
*** $p \leq 0,001$

TABLE 4: MEAN VALUES▲ FOR PHYSICAL CHARACTERISTICS OF HIGH-FIBRE MUFFINS OF THREE FORMULAS WITHIN DIFFERENT BATTER AGES AND SERVED FRESHLY BAKED

	Compress-ibility (N)	Crust colour (L)	Crumb colour (L)	Volume (ml)	Height (mm)	Weight loss (%)	Moisture (%)
Formula 1: Full-fat control							
Batter freshly prepared	5,0	35,2	40,0	$912,6^{x}$	$40,3^{x}$	$13,2^{x}$	38,2
Batter refrigerated 24 h	5,4	37,3	41,0	$859,8^{y}$	$37,8^{y}$	$11,9^{y}$	37,3
Batter refrigerated 48 h	5,5	34,9	40,3	$823,4^{z}$	$36,3^{z}$	$11,1^{y}$	37,4
Significance	NS	NS	NS	***	***	***	NS
Formula 2: 80% oil replacement◆							
Batter freshly prepared	6,3	$37,6^{y}$	$42,6^{y}$	$993,3^{x}$	$43,3^{x}$	$13,7^{x}$	42,4
Batter refrigerated 24 h	6,8	$40,5^{x}$	$45,5^{x}$	$973,8^{y}$	$43,2^{x}$	$12,7^{y}$	42,0
Batter refrigerated 48 h	6,4	$37,5^{y}$	$43,8^{xy}$	$951,7^{z}$	$41,9^{y}$	$11,0^{z}$	42,3
Significance	NS	*	*	***	***	***	NS
Formula 3: 100% oil replacement							
Batter freshly prepared	7,0	40,9	$46,6^{y}$	$1003,9^{x}$	$44,3^{x}$	$13,9^{x}$	$44,1^{x}$
Batter refrigerated 24 h	7,3	42,5	$49,6^{x}$	$982,2^{y}$	$42,4^{y}$	$13,2^{x}$	$43,3^{y}$
Batter refrigerated 48 h	6,9	40,7	$46,7^{y}$	$968,2^{y}$	$42,8^{y}$	$11,5^{y}$	$42,5^{z}$
Significance	NS	NS	**	***	***	***	***

▲ Each mean is the average of values obtanied from n = 16 (4 per batch x 4 replications)

◆ Protein-based fat substitute: Simplesse® Dry 100

xyz Mean values with different superscripts in each column block, differ significantly regarding batter age

NS Not significant

* $p \leq 0,05$

** $p \leq 0,01$

*** $p \leq 0,001$

Within the full-fat control muffins, the sensory score for crumbliness at initial bite was decreased as batter storage time increased. The control muffins baked from refrigerated batter were less tender, less compressible and more adhesive than those baked from freshly prepared batter. The control muffins baked from 48 h refrigerated batter were rated significantly different for all the textural attributes, namely cell distribution and size, crumbliness at initial bite and after chewing, crumb tenderness and mouthfeel from those baked from freshly prepared batter. Some of these results correspond with the findings published by Dorko and Penfield (1993:582) which also showed that muffin crumbliness decreased with batter storage. The sensory results on compressibility were, however, not confirmed by the Instron results.

Within the muffins with 80% oil replacement cell distribution, cell size, crust tenderness and crumbliness were significantly affected by batter refrigeration. Contrary to the findings of Dorko and Penfield (1993:582) crumb tenderness and adhesiveness were not significantly affected by batter refrigeration.

In the case of the muffins with 100% oil replacement the effect of batter refrigeration was limited and decreased only the sensory ratings for crumbliness and crumb tenderness. Within both experimental muffins compressibility was not affected by batter refrigeration. These sensory results were confirmed by the Instron results.

Flavour Comparing the flavour of the muffins within each formula the full-fat control muffins and the muffins with partial oil replacement were significantly less typical when baked from 48 h refrigerated batter than baked from freshly prepared or 24 h refrigerated batters, respectively. Within the muffins with total oil replacement flavour was not significantly affected by batter refrigeration.

Volume and height Within the full-fat control muffins volume and height were significantly decreased with increased batter storage time. Some of these results correspond with Quinn's findings (1995:56), who also reported on declining height of baked muffins as batter storage time increased. Within the muffins with partial oil replacement volume was also significantly decreased with increased batter storage time. Although the height of the muffins baked from freshly prepared batter and 24 h refrigerated batter did not differ significantly, both were significantly higher than those baked from 48 h refrigerated batter.

In the case of the muffins with total oil replacement the volume and height of muffins were decreased significantly by batter refrigeration.

Percentage weight loss during baking Within the full-fat control muffins, the percentage weight loss of the muffins baked from refrigerated batters was significantly decreased. Within the muffins with partial oil replacement, the percentage weight loss was significantly decreased as batter storage increased. In the case of the muffins with total oil replacement only those baked from 48 h refrigerated batter showed a significant decrease in weight loss.

Moisture content Comparing the moisture content of the muffins baked from freshly prepared or refrigerated batter within each formula showed that moisture content was not affected by batter refrigeration within the full-fat control and muffins with partial oil replacement. In the case of the latter the sensory ratings reflected the analysed moisture content. These results correspond with those of Dorko and Penfield (1993:580) which also indicated that muffin moisture content was not affected by batter storage and that the sensory moistness ratings reflected the analysed moisture content. Within the muffins with total oil replacement the moisture content decreased with increased batter storage time.

Correlations between sensory attributes and other measures Correlations between sensory attributes and physical measures are summarised in Table 5. Significant correlations ($p<0,0001$) between sensory and physical measurements of crust and crumb colour lightness were found, indicating that colour lightness intensity ratings increased as lightness L values increased. Although the sensory measurement of compressibility did not correlate significantly with Instron measurements, significant correlations ($p<0,0001$) between sensory compressibility and cell size, crumb tenderness and crumbliness at initial bite were found, indicating that compressibility increased with increased cell size, tenderness and crumbliness. Significant ($p<0,0001$) negative correlations were found between the Instron measurement of compressibility and sensory ratings for crumb tenderness and crumbliness after chewing, indicating that the higher the force required to attain a specified compression (25%) of a sample, the lower it was rated by the sensory panel for tenderness and crumbliness.

TABLE 5: SIGNIFICANT# CORRELATIONS IN SENSORY ATTRIBUTES AND BETWEEN SENSORY ATTRIBUTES AND PHYSICAL MEASUREMENTS OF HIGH-FIBRE MUFFINS CONTAINING DIFFERENT LEVELS OF SIMPLESSE® AT THREE DIFFERENT BATTER AGES

ATTRIBUTES	APPEARANCE					TEXTURE										PHYSICAL					
	Top crust shape	Crust gloss	Crust colour lightness	Crust surface	Crumb colour lightness	Cell distribution	Cell size	Compress-ibility	Crust tenderness	Crumbliness initial bite	Crumbliness after chewing	Crumb tenderness	Adhesiveness	Mouthfeel moistness	FLAVOUR TYPICAL	Compress-ibility Instron	Crust colour (L)	Crumb colour (L)	Volume	Height	Moisture
Appearance																					
Top crust shape	-	0,71	0,61	0,84	0,70	0,58	0,60	NS	NS	NS	-0,53	NS	NS	0,54	NS	0,53	NS	0,53	0,74	0,72	0,69
Crust gloss	0,71	-	0,73	0,60	0,83	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0,54	NS	NS	0,82	0,80	0,80
Crust colour lightness	0,61	0,73	-	0,50	0,94	NS	NS	NS	-0,73	NS	-0,79	-0,59	0,66	NS	NS	0,79	**0,55**	0,78	0,85	0,84	0,93
Crust surface	0,84	0,60	0,50	-	0,63	0,55	0,55	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0,68	0,65	0,59
Crumb colour lightness	0,70	0,83	0,94	0,63	-	NS	NS	NS	-0,60	NS	-0,71	-0,52	0,58	NS	NS	0,76	NS	**0,67**	0,90	0,92	0,94
Texture																					
Cell distribution	0,58	NS	NS	0,55	NS	-	0,78	NS	NS	0,57	NS	NS	NS	NS	0,51	NS	NS	NS	NS	NS	NS
Cell size	0,60	NS	NS	0,55	NS	0,78	-	0,61	NS	0,59	NS	NS	NS	NS	0,57	NS	NS	NS	NS	NS	NS
Compressibility	NS	NS	NS	NS	NS	NS	**0,61**	-	0,51	**0,68**	**NS**	**0,76**	NS	NS	0,65	**NS**	NS	NS	NS	NS	NS
Crust tenderness	NS	NS	-0,73	NS	-0,60	NS	NS	0,51	-	0,54	0,85	0,80	-0,83	NS	NS	-0,72	-0,53	-0,80	NS	NS	-0,68
Crumbliness initial bite	NS	NS	NS	NS	NS	0,57	0,59	0,68	0,54	-	NS	0,63	-0,54	NS	0,61	NS	NS	NS	NS	NS	NS
Crumbliness after chewing	-0,53	NS	-0,79	NS	-0,71	NS	NS	NS	0,85	NS	-	0,78	-0,84	NS	NS	-0,75	NS	-0,78	-0,62	-0,60	-0,77
Crumb tenderness	NS	NS	-0,59	NS	-0,52	NS	NS	0,76	**0,80**	**0,63**	**0,78**	-	-0,76	NS	0,67	-0,67	NS	-0,64	NS	NS	-0,57
Adhesiveness	NS	NS	0,66	NS	0,58	NS	NS	NS	**-0,83**	-0,54	**-0,84**	**-0,76**	-	NS	NS	0,58	NS	0,63	NS	NS	0,63
Mouthfeel	0,54	NS	NS	NS	NS	NS	NS	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	-	NS	NS	NS	NS	0,64	0,61	0,56
Flavour																					
Typical	NS	NS	NS	NS	NS	0,51	0,57	0,65	NS	0,61	NS	0,67	NS	NS	-	NS	NS	NS	NS	NS	NS
Sweet	NS	NS	NS	NS	NS	NS	NS	-0,54	-0,53	-0,57	NS	-0,53	NS	NS	**NS**	NS	NS	NS	NS	NS	NS
Nutty	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**NS**	NS	NS	NS	NS	NS	NS
Compressibility Instron	0,53	0,54	0,79	NS	0,76	NS	NS	**NS**	-0,72	**NS**	**-0,75**	**-0,67**	0,58	NS	NS	-	0,72	0,84	0,68	0,69	**0,80**
Moisture content	0,69	0,80	0,93	0,59	0,94	NS	NS	**NS**	**-0,68**	**NS**	**-0,77**	**-0,57**	**-0,63**	**0,56**	NS	**0,80**	0,53	0,75	**0,92**	**0,91**	-
Volume	0,74	0,82	**0,85**	0,68	**0,90**	NS	NS	NS	NS	NS	-0,62	NS	NS	0,64	NS	0,68	0,52	0,67	-	**0,97**	0,92

: $p \leq 0,05$; $r > 0,5$ NS = not significant at $p \leq 0,05$ The correlations printed in bold are discussed in the text

Moisture content correlated significantly ($p<0,001$) with volume, height and mouthfeel, indicating that the muffins with higher moisture content exhibited larger volume, height and perceived moistness. Significant ($p<0,001$) negative correlations were, however, found between moisture content and crumb tenderness, crumbliness after chewing and adhesiveness, indicating that increased moisture content related to decreased tenderness, crumbliness and increased adhesiveness (a high rating related to absence of adhesiveness). These results correspond with some of Cauvain's findings (1991:86) which indicated that cake crumb with higher moisture levels was less crumbly and more cohesive. Cauvain (1991) stated that moisture content might be considered as the singlemost meaningful measurement related to texture of baked products. Sensory perceived moistness did not correlate significantly with any of the texture related attributes. Flavour also did not correlate significantly with sweet or nutty taste. Although moisture content plays an important role in determining the rate of microbial growth, moisture content did not correlate significantly with total AMP counts in this study, probably because these counts were all low.

Cluster analysis Taking a maximum Euclidian distance between types forming one unit in order to establish similarity of types, Formula 1 (full-fat control) with its combinations of different batter refrigeration periods, fell into one cluster with the other two formulas (with 80% and 100% oil replacement) and their combinations into a second cluster. This means that the full-fat control was evaluated similarly for all the sensory as well as physical attributes considered, but differently from the two experimental formulas.

CONCLUSION

The objective of this study was to examine the effects of batter refrigeration and oil replacement on the characteristics of high-fibre muffins. The main findings indicated that oil replacement had more pronounced effects on the characteristics of the muffins than either 24 h or 48 h refrigeration of the batter. It seems that the experimental muffins were more resistant and changed less during refrigeration than the control muffins. It was also noted that no yeasts or moulds were detected and that neither oil replacement nor batter refrigeration had any effect on total AMP counts of the baked products, indicating the safety of batter

refrigeration.

It is concluded that oil replacement resulted in products that showed better stability towards batter refrigeration than the full-fat control muffins. The results also indicated that the experimental muffins baked from refrigerated batter, although different from the freshly baked full-fat control muffins, were still of comparable quality as shown by the high mean ratings allocated for all the characteristics measured. Therefore, it can be recommended that where indicated the experimental low-fat high-fibre batter can be refrigerated for up to 48 hours without significant adverse effects on quality characteristics or microbiological safety.

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CHAPTER 7

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

In this chapter, the general discussion of the main findings of the studies reported in chapters 2 - 6 will focus on the effects of Simplesse® on some unique properties of muffins, indicating mainly that these properties were not adversely influenced by the protein-based fat substitute. It will also highlight the nutritional benefits of using Simplesse®. The discussion will be followed by general conclusions summarised from chapters 2 - 6, after which recommendations regarding the use of Simplesse® in baked products, the application of the results of the study as well as for further research in this field will be made.

7.2 DISCUSSION

The major motivation for this study was to develop a low-fat, high-fibre baked product of which the low-fat characteristic would not compromise sensory characteristics (texture, flavour, appearance) and acceptability, which are usually found to be problematic with many high-fibre products. The desirability of a low-fat high-fibre diet was fully motivated in chapter 1. Muffins were chosen for this project because they are convenient, easy to prepare and are an ideal vehicle to add fibre to the diet. In addition they are eaten regularly by many people who wish to reduce fat and increase fibre intake.

A major question that should be asked, is whether or not the objectives, stated in chapter 1, were indeed met.

With reference to objective 1.3.2.1, a high-fibre (± 7%) muffin containing less than 3 g total fat per 60 g serving size was developed by using Simplesse® as fat substitute. The analytical panel evaluated the sensory qualities of the developed product in comparison to those of the full-fat control muffins. Consequently the first objective regarding the development of the specified low-fat muffin was met.

With reference to objective 1.3.2.2, the results indicated that the muffins with 80% replacement of oil with Simplesse® were scored higher than or similar to the full-fat control on most attributes except for some of the textural attributes such as compressibility, crumbliness and tenderness. Although the muffins with 100% replacement of oil with Simplesse® differed significantly from the full-fat control muffins on the textural attributes and flavour, their scores still indicated high quality. It can thus be concluded that the second objective was successfully met.

With reference to objective 1.3.2.3, it was found that the muffins with non-fat milk solid were scored significantly lower on all attributes than the muffins with Simplesse® and were found to be inferior in quality. The third objective was met in that the effect of fat replacement with non-fat milk solids could be determined undisputedly.

Pertaining to the first three objectives, this study demonstrated that Simplesse® can successfully replace fat up to 100% in high-fibre muffins without serious adverse effects on quality. It further demonstrated that non-fat milk solids cannot replace fat in high-fibre muffins as successfully as Simplesse®.

With reference to objective 1.3.2.4, dietitians seemed to be well aware of fat substitutes in general, research on fat substitutes and their safety. The dietitians were also knowledgeable regarding the dietary advantages of using fat substitutes. The fourth objective was met in that the awareness and knowledge of dietitians regarding fat substitute such as Simplesse® were determined.

With reference to objective 1.3.2.5, the dietitians were informed about the characteristics and application of fat substitutes such as Simplesse® in order to enable them to partake in the rest of the study.

With reference to objective 1.3.2.6, the sensory results indicated that the low-fat, high-fibre muffins prepared with Simplesse® were extremely acceptable to the dietitians, and that they did not prefer the full-fat control to the experimental muffins. The dietitians also expressed an intention of regularly eating the products. These findings might reflect their positive attitude towards the muffins prepared with Simplesse®.

With reference to objective 1.3.2.7, a reliable and valid attitude scale was developed and administered to the dietitians to determine their attitude towards issues regarding fat substitutes.

The results reflected that the dietitians who participated in this study did not seem to have serious problems with fat limitation in the treatment of their patients. They were, however, convinced of the advantages of and the need for fat substitutes such as Simplesse®, *inter alia* in providing a greater variety of low-fat foods. The seventh objective was thus met successfully.

With reference to objective 1.3.2.8, the sensory results indicated that although the consumers preferred the full-fat control muffins and perceived these to be more acceptable than the muffins with Simplesse®, the latter were still scored as highly acceptable on all the attributes. The consumers also revealed a positive attitude to all the muffin variations by declaring their intention to eat the control muffins and the muffins with 80% replacement every day and those with 100% replacement of oil with Simplesse® once a week. Consequently the eighth objective was met successfully.

With reference to objective 1.3.2.9, the results indicated that the weight control variables, with the exception of using sugar-free products and avoiding sugar, did not seem to influence the acceptance or intended consumption of the muffins.

With reference to objective 1.3.2.10, the study revealed that oil replacement was the major source of significant variation regarding all attributes measured, while storage period and temperature showed significant variation to a minor extent. The use of Simplesse® seemed to enhance the attributes of appearance, and to maintain the flavour and some of the textural attributes of freshly baked high-fibre muffins. Most of the textural attributes, such as crumbliness, tenderness and adhesiveness were adversely affected. The microbial counts were low and no significant differences were found between the mean total bacterial counts of the muffins within each storage period. When focusing on the effects of storage within each formula it was found that the muffins with 80% oil replacement showed fewer attribute changes after 24 h storage at room temperature but showed more attribute changes due to frozen storage than the full-fat control and the muffins with total oil replacement. The conclusion that muffins containing Simplesse® can be stored for 24 h at room temperature without remarkable additional adverse effects, but cannot be frozen as successfully, makes an unique contribution to knowledge regarding storage of baked products with oil replacement. The tenth objective was therefore also successfully met.

With reference to objective 3.1.2.11, the findings also indicated that oil replacement had more pronounced effects on the characteristics of the muffins than did the refrigeration of the batter. It

seemed that the experimental muffins were more resistant and changed less during refrigeration than the control muffins. No yeast or moulds were detected and neither oil replacement nor batter refrigeration had any effect on total AMP counts of the baked products, indicating the safety of batter refrigeration. It was concluded that oil replacement with Simplesse® resulted in products that showed better stability towards batter refrigeration than the full-fat control muffins. The results also indicated that the experimental muffins baked from refrigerated batter, although different from the freshly baked full-fat control muffins, were still of comparable quality as shown by the high mean ratings allocated for all the characteristics measured. It can thus be stated that the eleventh objective was met. It could also be recommended that the experimental low-fat high-fibre batter can be refrigerated for up to 48 hours without significant adverse effects on quality characteristics or microbiological safety.

In summary this project indicated that, although the trained analytical panel indicated some significant differences among the characteristics of the developed experimental muffins and the full-fat control muffins, dietitians and a consumer panel still found the experimental muffins highly acceptable.

The question that immediately arises from the above observation, is to what extent a new product must meet scientific evaluation goals before it can be considered a "successful" product? In this study both dietitians and consumers had to evaluate acceptability of appearance, texture and flavour. They also had to reveal preference and consumption intent. Baker *et al.* (1994:12) argued that the consumer is the key to the success of new products as it is the consumer who decides whether the food is acceptable or not. The results of this study therefore support the finding of Armbrister and Setser (1994:350), viz. that if a trained panel finds differences among control and experimental products, it does not necessarily mean that these products will be found unacceptable by consumers. It should be noted, however, that in this study the statistically significant differences indicated by the trained analytical panel were relatively small. This may explain why the dietitians and consumers found the experimental muffins highly acceptable, despite significant differences.

It was also found that the effects of storage period and temperature on the sensory characteristics were less than the effects of oil replacement. The microbial counts of the different muffin formulas were low and no significant differences were found. From the above it is clear that the

fat substitute Simplesse® had no detrimental effect on the safety (microbial counts) or storage stability of the experimental muffins.

The results of experimentation with batter refrigeration indicated that the stability of the batters of the experimental muffins containing the fat substitute, Simplesse®, was actually better than that of the full-fat control muffins. This finding has important applications for a convenience product, as it implies that the batter can be refrigerated successfully to produce freshly baked muffins. As indicated in chapter 6 there is currently a world-wide focus on the production of freshly baked products (Faridi, 1995:7; Gibson, 1995:16; Sloan, 1994:89). The fact that a high-fibre product such as these muffins containing Simplesse® can be successfully baked from refrigerated batter, is a new finding, which would benefit all institutions providing freshly baked products, especially low-fat, high-fibre baked products which could benefit consumers by providing them with a very convenient way to incorporate more fibre in a modern lifestyle diet. This finding can also be applied in households where individuals are aiming to decrease fat and increase fibre intake and still have a high-quality freshly baked convenience product.

The nutritional benefits of the developed low-fat high-fibre product are numerous. The main nutritional advantage of fat substitution with Simplesse® is a considerable reduction in fat while the fibre content remains high. The full-fat control muffin (60 g) provides 4,5 g fibre which equals 20% of total daily intake and 7,9 g fat, representing 12,5% fat allowance on an 8 000 kJ diet. With 80% oil replacement each muffin contains only 2,5 g fat, while with 100% oil replacement it contains only 1,3 g fat, representing fat reductions of 68% and 84%, respectively, and providing only 2-4% of the recommended fat compared to 12,5% fat supplied by the full-fat control. Both products with Simplesse® qualify for the low-fat claim having less than 3 g fat/serving unit.

An important aspect of this study was the finding that dietitians were convinced of the advantages of and the need for fat substitutes such as Simplesse®, which could possibly predict a positive behavioural intention towards the product. The dietitians did not prefer the full-fat control muffins to the experimental muffins and revealed a very positive attitude towards all the muffin variations by declaring their intention of eating them once a week.

Although the sub-studies showed that there were small but significant effects of Simplesse® on textural attributes, none of these was large enough to influence consumption intent by consumers

to any great extent. This may possibly be ascribed to the fact that extremely small effects of the fat replacer on flavour were observed.

From the above discussion it seems that Simplesse® is a highly suitable replacement for oil in a muffin product. However, this does not mean that no adverse effects on compressibility, crumbliness and adhesiveness resulted from using Simplesse®. As mentioned above, none of these was large enough to elicit a negative response or attitude and advise against the use of Simplesse®.

This study showed that it is possible to successfully replace oil in muffins with Simplesse®. However, the effects of long-term intake of Simplesse® and other fat substitutes have not been studied in-depth. It is therefore recommended that long-term health benefits (lowering of fat intake) and possible disadvantages (whey protein allergies in certain individuals) should receive attention in follow-up studies. Furthermore, nutrition labelling is necessary to help consumers translate dietary recommendations into practical terms. The muffins developed in this project contained 6,8 to 7,2 g fibre/100 g baked product and only 2,1 to 4,3 g fat/100 g. It is possible that this product could qualify for future health claim labelling in South Africa (Booysen, 1998).

7.3 CONCLUSIONS

It is generally concluded from the results of this study that the protocol used for the evaluation of a low-fat high-fibre baked product is suitable and that non-fat milk solids (NFMS) cannot replace oil in high-fibre muffins as successfully as Simplesse®.

It is further concluded that Simplesse® is a highly successful fat replacer in high-fibre muffins. The high-fibre muffins were perceived to be highly acceptable by health professionals (dietitians) and consumers. The analytical panel indicated only small differences between the experimental muffins and the full-fat control muffins. However, the differences from the control muffins do not necessarily imply that the muffins would be unacceptable to consumers (Armbrister & Setser, 1994:350).

The reader is also referred to specific conclusions resulting from the different sub-studies which were made at the end of chapters 2 - 6 respectively.

7.4 RECOMMENDATIONS

7.4.1 Practical recommendations regarding the use of Simplesse®

Contrary to the recommendations by NutraSweet (1994) and Corliss (1992:4), to reduce or completely eliminate eggs in the formula when using Simplesse®, experimentation during the pilot study clearly confirmed the functional contribution of lecithin and egg protein to the quality characteristics of the high-fibre muffins (specially if no other stabilisers or emulsifiers are used).

According to the results in the pilot study it is also recommended to bake the wheat bran (4 h at 100°C) prior to use to obtain a more nutty flavour; to hydrate the baked wheat bran in warm water and to hydrate the mixed batter containing Simplesse® Dry 100 1 h prior to baking to improve the flavour and texture of the muffins.

7.4.2 Recommendations regarding applications of this research

Low-fat high-fibre muffins were developed to use in the Lipid-clinic. The Lipid-clinic is a specialised clinic of the Potchefstroomse Universiteit vir Christelike Hoër Onderwys where hypercholesterolaemic patients are treated with lipid lowering diets and drugs and monitored on a regular basis. The results of the study about the effect of Simplesse® on the storage stability clearly indicated that it will also be a suitable product for fast food outlets and institutions.

It is further recommended that if and when commercially available, these muffins should be labelled as a low-fat high-fibre muffin suitable for the prudent diet advised for diabetics and patients with hypercholesterolaemia and CHD.

7.4.3 Recommendations regarding further research

The protocol used in this study could also be used for the development of other low-fat high-fibre popular traditional baked products such as high-fibre quick breads, cakes and brandy tarts as well as for baked products low in moisture, such as low-fat shortbread, cookies and crackers.

Further research using other fat substitutes such as Olestra, Litesse™, emulsifiers such as glycerol monostearate (GMS) or modified starches in combination with non-nutritive sweeteners to reduce the fat content and kilojoule value, is recommended.

Research implementing partial or total replacement of wheat bran with oat bran, vegetable or fruit fibre to increase the soluble fibre content could also make a contribution. The addition of grated carrots or dried fruit such as currants, sultanas, seedless raisins or dried apricot pieces could contribute more fibre, variety and enhanced flavour and texture as well as additional micronutrients.

Investigative studies should be done on consumers' perceptions of and attitude towards fat substitutes, products containing fat substitutes and low-fat or reduced-kilojoule foods. Studies to characterise the nature and mechanism of altered food acceptability during adherence of a reduced fat diet should also be conducted.

Results from this and other recommended studies will, however, only have practical benefits if consumers are informed about the advantages, safety and use of reduced-fat products in their diets.

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CONGRESS PRESENTATIONS

CONGRESS PRESENTATIONS

The following papers and posters, based on this thesis, have been presented:

Bosman MJC, Vorster HH, Drewnowski A, Steyn HS & Schönfeldt HC. 1995. Characteristics of high-fibre muffins containing various levels of fat substitute. (*In* Proceedings of the thirteenth biennial congress of the South African Association for Food Science and Technology (SAAFoST) and Institute of Food Technologists (IFT): Technology and ingredient update Durban, 29 August - 1 September 1995.)

Bosman MJC & Vorster HH. 1997. Consumer acceptance of high-fibre muffins containing Simplesse®. (*In* Proceedings of the fourteenth SAAFOST and ICC : Harnessing food science and technology for sustainable development. Pretoria, 1 - 4 September 1997.)

Bosman MJC, Reitsma GM & Vorster HH. 1997. Compressibility and tenderness of high-fibre muffins containing Simplesse® (Poster). (*In* Proceedings of the fourteenth SAAFoST International Congress in conjunction with ECSAFoST and ICC : Harnessing food science and technology for sustainable development. Pretoria, 1 - 4 September 1997.)

Bosman MJC, Vorster HH & Drewnowski A. 1997. Dietitians' attitude towards fat substitutes and the acceptability of high-fibre muffins containing Simplesse® (Poster). (*In* Proceedings of the fourteenth SAAFOST International Congress in conjunction with ECSAFoST and ICC : Harnessing food science and technology for sustainable development. Pretoria, 1 - 4 September, 1997.)

Bosman MJC, Van Aardt AM, Silvis N, Vorster HH & Drewnowski A. 1998. High-fibre muffins containing a fat substitute : an attitude and acceptability study among dietitians (Poster). (*In* Proceedings of the sixteenth ICC conference of the International Association for Cereal Science and Technology : Cereal Science - its contribution to health and well being. Vienna, Austria, 9 - 12 May.)

Bosman MJC, Reitsma GM & Vorster HH. 1998. Compressibility and tenderness of high-fibre muffins containing Simplesse® (Poster). (*In* Proceedings of the sixteenth ICC conference of the International Association for Cereal Science and Technology : Cereal Science - its contribution to health and well being. Vienna, Austria, 9 - 12 May.)

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Bosman MJC, Van Aardt AM, Silvis N, Vorster HH & Drewnowski A. 1998. High-fibre muffins containing a fat substitute : an attitude and acceptability study among dietitians (Poster). (*In* Book of abstracts of the fifth biennial congress of the Association for Dietetics in South Africa and 17th biennial congress of the Nutrition Society of Southern Africa: Nutrition in the news. Sun City, 25 - 29 May.)

ADDENDA

ADDENDUM REGARDING THE FORMULAS AND MACRONUTRIENT COMPOSITION OF THE MUFFINS EVALUATED IN THIS STUDY

Langenhoven, M.L., Conradie, P.J., Wolmarans, P. & Faber, M. 1991. Medical Research Council Food Quantities Manual. 2nd ed. Tygerberg: The Medical Research Council. 213 p.

NutraSweet Europe. 1993. Nutritional Data: Simplesse® Dry 100 Dehydrated Microparticulated whey protein concentrate. France: Bièvres Cedex.

TABLE: MUFFIN FORMULAS AND MACRONUTRIENT COMPOSITION (Langenhoven *et al.*, 1991; NutraSweet, 1993)

Ingredients (g)				Nutrient composition/100 g					Formula 1					Formula 2					Formula 3				
Ingredients	For-mula 1	For-mula 2	For-mula 3	kJ	Fat	Fib	Prot	CHO	kJ	Fat	Fib	Prot	CHO	kJ	Fat	Fib	Prot	CHO	kJ	Fat	Fib	Prot	CHO
Wheat bran[a]	130	130	130	902	4,3	42,4	15,6	22,1	1172,6	5,6	55,1	20,3	28,7	1172,6	5,6	55,1	20,3	28,7	1172,6	5,6	55,1	20,3	28,7
Water I	200	200	200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Water II	-	70	110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sugar[b]	150	150	150	1612	-	-	-	99,5	2418	-	-	-	149,3	2418	-	-	-	149,3	2418	-	-	-	149,3
Sunflower oil[i]	100	20	-	3699	100	-	-	-	3699	100	-	-	-	740	20	-	-	-	-	-	-	-	-
Fresh egg[c]	50	50	50	637	10,3	-	12,6	1,2	319	5,2	-	6,3	0,6	319	5,2	-	6,3	0,6	319	5,2	-	6,3	0,6
Yoghurt (low fat)[d]	250	250	250	265	1,6	-	5,3	7	663	4,0	-	13,3	17,5	663	4,0	-	13,3	17,5	663	4,0	-	13,3	17,5
Baking soda[e]	5	5	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whole wht. flour[f]	75	75	75	1420	1,9	12,6	13,7	60	1065	1,4	9,5	10,3	45	1065	1,4	9,5	10,3	45	1065	1,4	9,5	10,3	45
Cake flour[g]	75	75	75	1515	0,9	2,7	8,2	75,3	1136	0,7	2,0	6,2	56,5	1136	0,7	2,0	6,2	56,5	1136	0,7	2,0	6,2	56,5
Salt[h]	2,5	2,5	2,5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Simplesse® Dry 100[j]	-	50	80	1495,2	4,1	-	49,6	30,1	-	-	-	-	-	748	2,1	-	24,8	15	1196,2	3,3	-	39,7	24,1
Tot. mass batter	1037,5	1077,5	1127,5	Total macronutrients					10472, 6	117	66,6	56,4	297,6	8261,6	39,0	66,6	81,2	312,6	7969,8	20,3	66,6	96,1	321,7
Average weight loss % project 1	13,4	13,4	13,45	Nutrient value 70g batter/±60g baked muffin project 1					706,6	7,9	4,5	3,8	20,1	536,7	2,5	4,3	5,3	20,3	494,8	1,3	4,1	6,0	20,0
Tot. mass baked	898,5	933	976	Nutrient value/100g baked project 1					1166	13	7,4	6,3	33,1	885	4,2	7,2	8,7	33,5	816	2,1	6,8	9,9	33,0
Number of muffins	14	15	16																				

a Digestive bran, Snowflake, Premier Foods
b Illovo Ltd
c Grade 1, Top Lay
d Low fat plain Swiss style, Clover
e Royal, Royal Beech-Nut
f Nutty wheat, Snowflake, Premier Foods
g Snowflake, Premier Foods
h Iodised, Cerebros
i Excella, Senwesko
j Simplesse® Dry 100, Simplesse Co., Deerfield, IL

ADDENDA REGARDING PANEL PERFORMANCE EVALUATION DURING THE PILOT STUDY

* Procedure
* Panel performance evaluation sheet: muffin project 1
* Prestasie evalueringsvorm: muffinprojek 1
* Table 1: Reliability coefficients (project 1)

SENSORY PANEL'S PERFORMANCE EVALUATION

At the end of the training programme the performance of each panellist as well as the sensory panel's performance were evaluated in order to determine the repeatability of their evaluations. Four evaluation sessions were conducted during which a set of two duplicate samples which the panel leader knew to be different were served to the panel (4 samples/session).

Analysis of variance (ANOVA) was conducted by means of the Statistical Analysis System (SAS) which indicated that the muffin samples differed significantly ($p<0,01$) from each other as far as all the sensory attributes were concerned.

Furthermore, the inter and intra-sensory panellist variances were determined and the coefficient of reliability of the sensory panel for each sensory attribute subsequently calculated according to the following formula:

$$\text{Coefficient of reliability} = 1 - \frac{\text{within-panellist variance}}{\text{between-panellist variance}}$$

$$= 1 - \frac{\text{mean square error } S_W^2}{\text{mean square model } S_B^2}$$

The coefficient of reliability was also calculated for each panellist relative to each sensory attribute by one-way ANOVA.

$$\text{Reliability of individual panellist} = \frac{F-1}{F} \quad \text{(Winer, 1991)}$$

F = Variance proportion as derived from ANOVA.

The reliability coefficients for the sensory panel and the individual panellists for the different sensory attributes are presented in Tables 1 and 2. Values of 1.0 represent very high levels of reliability of the sensory panel and individual panellists.

Results obtained (Tables 1 and 2) indicate that the sensory panel consisting of eight members, was adequately trained and could be regarded as an accurate scientific measuring instrument.

PANEL PERFORMANCE EVALUATION SHEET: MUFFIN PROJECT I

EVALUATE THE SAMPLES IN THE SPECIFIED ORDER WITH RESPECT TO THE GIVEN CRITERIA. WRITE THE RATINGS (1-6) IN THE APPROPRIATE BLOCKS

CRITERIA

[A rating of six is the highest rating and one the least relative to the reference standards set for high quality for each attribute.]

Panelist's number					01
Session					02
Order	1	2	3	4	03
Sample code					
Formula					04-06

1. APPEARANCE

1.1 Top crust shape
1 - Asymmetrical/Peaks/Flat
6 - Symmetrical, slightly rounded — 07

1.2 Crust gloss
1 - Very glossy
6 - Slightly glossy — 08

1.3 Crust colour
1 - Too light/too dark brown
6 - Dark golden brown — 09

1.4 Crust surface
1 - Very smooth
6 - Coarse/pebbled — 10

1.5 Crumb colour brown
1 - Too light/too dark
6 - Dark golden brown — 11

2. TEXTURE

2.1 Cell distribution
1 - Uneven (tunnels)
6 - Even (no tunnels) — 12

2.2 Cell size
1 - Small cells (Compact)
6 - Large cells (Loose) — 13

Order	1	2	3	4	03
Sample code					
Formula					04-06

2.3 Compressibility
1 - Not easily compressed, firm and stiff
6 - Easily compressed, not firm

14

2.4 Crust toughness
1 - Very tough
6 - Firmer as the crumb, but not tough

15

2.5 Cohesiveness of mass at initial bite
1 - Very cohesive - clumped together (cloggy)
6 - Not cohesive - loose (not cloggy at all)

16

2.6 Cohesiveness of mass after chewing
1 - Very cohesive - ball-like mass (cloggy)
6 - Not cohesive - loose (not cloggy at all)

17

2.7 Tenderness
1 - Not tender - Firm
6 - Tender

18

2.8 Adhesiveness (toothpacking)
1 - Sticks to the teeth
6 - Does not stick to the teeth

19

3. FLAVOUR

3.1 1 - Atypical (taint/aftertaste)
6 - Typical without any taints
(nutty, not too sweet)

20

Specify any taint or sharp/intense flavour or aftertaste

.....

.....

4. OVERALL QUALITY

1 - Not according to standards
6 - According to standards

21

THANK YOU FOR YOUR PARTICIPATION

PRESTASIE EVALUERINGSVORM: MUFFINPROJEK I

EVALUEER DIE MONSTERS TEN OPSIGTE VAN GENOEMDE KRITERIA IN DIE VOLGORDE SOOS AANGEDUI. VUL TOEGEKENDE WAARDES (1-6) IN BETROKKE RUIMTES IN.

KRITERIA

['n Waarde van ses is die hoogste waarde en een van die laagste relatief tot die standaard vir hoë kwaliteit ten opsigte van elke eienskap gestel.]

Proepaneellidnommer					01
Sessienommer					02
Volgorde	1	2	3	4	03
Monsterkode					
Formule					04-06

1. VOORKOMS

1.1 Bokorsvorm
1 - Asimmetries/Pieke/Plat
6 - Simmetries, Effens gerond

				07

1.2 Korsglans
1 - Baie glansend
6 - Effens glansend

				08

1.3 Korskleur
1 - Te lig/te donker bruin
6 - Donker goudbruin

				09

1.4 Korsoppervlak
1 - Baie glad
6 - Hobbelrig (blomkool)

				10

1.5 Kruimkleur
1 - Te lig/te donker bruin
6 - Donker goudbruin

				11

2. TEKSTUUR

2.1 Selverspreiding
1 - Oneweredig (tonnels)
6 - Eweredig (geen tonnels)

				12

2.2 Selgrootte
1 - Klein selle (kompak)
6 - Groot selle (los)

				13

	Volgorde	1	2	3	4	03
	Monsterkode					
	Formule					04-06
2.3	Saamdrukbaarheid 1 - Moeilik saamdrukbaar, ferm 6 - Besonder saamdrukbaar, nie ferm					14
2.4	Korstaaiheid met eerste byt 1 - Baie taai 6 - Fermer as kruim maar nie taai					15
2.5	Klewerigheid van deeltjies tydens eerste koufase (kohesie) 1 - Baie klewerig - kluitjierig en vas 6 - Glad nie klewerig - los, klam, nie kluitjierig					16
2.6	Klewerigheid v deeltjies onderling na koufase 1 - Baie klewerig - vorm 'n bal (kluitjierig) 6 - Glad nie klewerig - los, klam					17
2.7	Sagtheid 1 - Nie sag - ferm 6 - Sag					18
2.8	Klewerigheid van deeltjies aan tande (adhesie) 1 - Kleef aan tande vas 6 - Kleef glad nie aan tande					19
3.	**SMAAK**					
3.1	1 - Nie tipies (bysmaak/nasmaak) 6 - Tipies (neuterig, nie te soet)					20
	Spesifiseer enige bysmaak of intense smaak of nasmaak					
4.	**TOTALE KWALITEIT**					
	1 - Nie volgens standaarde gestel 6 - Volgens standaarde gestel					21

BAIE DANKIE VIR U DEELNAME

TABLE 1: Reliability coefficients of the sensory panel and individual panellists for different sensory attributes (Project 1)

Criteria	Panel	Panellist 1	Panellist 2	Panellist 3	Panellist 4	Panellist 5	Panellist 6	Panellist 7	Panellist 8
1. Appearance									
1.1 Top crust shape	0.9961	0.9803	0.9771	0.9600	0.9873	0.9312	0.9727	0.9600	0.9806
1.2 Crust gloss	0.9712	1.0000	0.7778	0.9994	1.0000	0.4945	0.5445	0.7500	0.9375
1.3 Crust colour	0.9969	0.9679	0.9762	0.9562	0.9821	0.9540	0.9913	0.9829	0.9913
1.4 Crust surface	0.9968	0.9866	0.9841	0.9913	0.9841	0.9306	0.9913	0.9606	0.9913
1.5 Crumb colour	0.9955	0.9600	0.9879	0.9998	0.9665	0.5170	0.9464	0.9913	0.9829
2. Texture									
2.1 Cell distribution	0.9966	0.9681	0.9841	0.9956	0.9306	0.9623	0.9839	0.9841	0.9913
2.2 Cell size	0.9967	0.9681	0.9913	0.9912	0.9030	0.9371	0.9956	0.9898	0.9873
2.3 Compressibility	0.9964	0.9998	0.9998	0.9829	0.9873	0.9330	0.9778	0.9839	0.9762
2.4 Crust toughness	0.9972	0.9844	0.9300	0.9900	1.0000	0.9630	0.9600	0.9421	0.9900
2.5 Cohesiveness (initial bite)	0.9960	0.9796	0.8980	0.9844	0.8776	0.9375	0.9630	0.9796	0.9796
2.6 Crumb tenderness	0.9930	0.9600	0.9603	0.9841	0.9371	0.8000	0.9286	0.9781	0.9800
2.7 Cohesiveness (after chewing)	0.9939	0.9844	0.9592	0.9444	0.9167	0.9444	0.8889	0.9600	0.9917
2.8 Adhesiveness	0.9955	0.9844	0.9592	0.8611	0.9844	0.9444	0.9444	0.9375	0.9844
3. Flavour	0.9989	0.9998	0.9998	0.9998	0.9867	0.9445	0.9998	0.9965	0.9879
4. Overall Quality	0.9971	0.9841	0.9876	0.9829	0.9796	0.9457	0.9841	0.9873	0.9877

ADDENDA REGARDING SENSORY EVALUATION REPORTED IN CHAPTER 2

* Sensory evaluation sheet: muffin project 1
* Sintuiglike evalueringsvorm: muffinprojek 1

SENSORY EVALUATION SHEET: MUFFIN PROJECT I

EVALUATE THE SAMPLES IN THE SPECIFIED ORDER WITH RESPECT TO THE GIVEN CRITERIA. WRITE THE RATINGS (1-6) IN THE APPROPRIATE BLOCKS

CRITERIA

[A rating of six is the highest and one the least relative to the reference standards set for high quality for each attribute.]

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Session						02
Order	1	2	3	4	5	03
Sample code						
Formula						04-06
1. APPEARANCE						
1.1 Top crust shape 1 - Asymmetrical/Peaks/Flat 6 - Symmetrical, slightly rounded						07
1.2 Crust gloss 1 - Very glossy 6 - Slightly glossy						08
1.3 Crust colour 1 - Too light/too dark brown 6 - Dark golden brown						09
1.4 Crust surface 1 - Very smooth 6 - Coarse/pebbled						10
1.5 Crumb colour 1 - Too light/too dark brown 6 - Dark golden brown						11
2. TEXTURE						
2.1 Cell distribution 1 - Uneven (tunnels) 6 - Even (no tunnels)						12
2.2 Cell size 1 - Small cells (compact) 6 - Large cells (loose)						13

	Order	1	2	3	4	5	03
	Sample code						
	Formula						04-06
2.3	Compressibility 1 - Not easily compressed, firm 6 - Easily compressed, not firm						14
2.4	Crust toughness 1 - Very tough 6 - Firmer as the crumb, but not tough						15
2.5	Cohesiveness of mass at initial bite 1 - Very cohesive - clumped together 6 - Not cohesive - loose (not cloggy at all)						16
2.6	Cohesiveness of mass after chewing 1 - Very cohesive - ball-like mass (cloggy) 6 - Not cohesive - loose (not cloggy at all)						17
2.7	Tenderness 1 - Not tender - Firm 6 - Tender						18
2.8	Adhesiveness (toothpacking) 1 - Sticks to the teeth 6 - Does not stick to the teeth						19
3.	**FLAVOUR**						
3.1	1 - Atypical (taint/aftertaste) 6 - Typical without any taints (nutty, not too sweet)						20
	Specify any taint or sharp/intense flavour or aftertaste						
4.	**OVERALL QUALITY**						
	1 - Not according to standards 6 - According to standards						21

THANK YOU FOR YOUR PARTICIPATION

SINTUIGLIKE EVALUERINGSVORM: MUFFINPROJEK I

EVALUEER DIE MONSTERS TEN OPSIGTE VAN GENOEMDE KRITERIA IN DIE VOLGORDE SOOS AANGEDUI. VUL TOEGEKENDE WAARDES (1-6) IN BETROKKE RUIMTES IN.

KRITERIA

['n Waarde van ses is die hoogste en een die laagste relatief tot die standaard vir hoë kwaliteit ten opsigte van elke eienskap gestel.]

Proepaneellidnommer						01
Sessienommer						02
Volgorde	1	2	3	4	5	03
Monsterkode						
Formule						04-06

1. VOORKOMS

1.1 Bokorsvorm
1 - Asimmetries/Pieke/Plat
6 - Simmetries, Effens gerond

1.2 Korsglans
1 - Baie glansend
6 - Effens glansend

1.3 Korskleur
1 - Te lig/te donker bruin
6 - Donker goudbruin

1.4 Korsoppervlak
1 - Baie glad
6 - Hobbelrig (blomkool)

1.5 Kruimkleur
1 - Te lig/te donker bruin
6 - Donker goudbruin

					07
					08
					09
					10
					11

2. TEKSTUUR

2.1 Selverspreiding
1 - Oneweredig (tonnels)
6 - Eweredig (geen tonnels)

2.2 Selgrootte
1 - Klein selle (kompak)
6 - Groot selle (los)

					12
					13

	Volgorde	1	2	3	4	5	03
	Monsterkode						
	Formule						04-06
2.3	Saamdrukheid 1 - Moeilik saamdrukbaar, ferm 6 - Besonder saamdrukbaar, nie ferm						14
2.4	Korstaaiheid met eerste byt 1 - Baie taai 6 - Fermer as kruim maar nie taai						15
2.5	Klewerig van deeltjies tydens eerste koufase (kohesie) 1 - Baie klewerig - kluitjierig en vas 6 - Glad nie klewerig - los, klam, nie kluitjierig						16
2.6	Klewerigheid v deeltjies onderling na koufase 1 - Baie klewerig - vorm 'n bal (kluitjierig) 6 - Glad nie klewerig - los, klam						17
2.7	Sagtheid 1 - Nie sag - Ferm 6 - Sag						18
2.8	Klewerigheid van deeltjies aan tande (adhesie) 1 - Kleef aan tande vas 6 - Kleef glad nie aan tande						19
3.	**SMAAK**						
3.1	1 - Nie tipies (bysmaak/nasmaak) 6 - Tipies (neuterig, nie te soet)						20
	Spesifiseer enige bysmaak of intense smaak of nasmaak						
4.	**TOTALE KWALITEIT**						
	1 - Nie volgens standaarde gestel 6 - Volgens standaarde gestel						21

DANKIE VIR U DEELNAME

ADDENDA REGARDING THE STUDY REPORTED IN CHAPTER 3

* Questionnaire for dietitians (Group 1)
* Vraelys vir dieetkundiges (Groep 1)
* Questionnaire for dietitians (Group 2)

QUESTIONNAIRE FOR DIETITIANS: STRICTLY CONFIDENTIAL (GROUP 1)

QUESTIONNAIRE NO. | | | |

*** Mark the appropriate square with a cross (X)**

SECTION A/I

DEMOGRAPHIC INFORMATION

1. SEX

For office use only

Male	1
Female	2

2. CAREER

Clinical dietitian	1
Administrative dietitian	2
Community dietitian	3
Dietitian - other	4

3. AGE

Between 21 and 30 years	1
Between 31 and 40 years	2
Older than 40 years	3

4. DATE OF COMPLETION OF STUDIES

Before 1960	1
Between 1961-1970	2
Between 1971-1980	3
Between 1981-1990	4
After 1990	5

KNOWLEDGE AND ATTITUDE QUESTIONNAIRE: *SIMPLESSE*

SECTION B/2: Knowledge/awareness regarding fat substitutes such as *Simplesse.*

Answer the following questions by marking the appropriate square with a cross (X)

		Yes	No	For office use only
1.	Did you have knowledge of fat substitutes before this meeting?			
2.	Did you have knowledge of *Simplesse* specifically before this meeting?			
3.	Do fat substitutes reduce the energy content of products?			
4.	Is *Simplesse* safe to use?			
5.	Has any research been done on the physiological effects of *Simplesse* as a fat substitute?			
6.	Are you aware of research about the use of fat substitutes in product development?			

7*. How is *Simplesse* made?

i	by purifying cellulose derivatives		1
ii	by microparticulation of milk/egg white protein		2
iii	by esterification of sucrose and fatty acids		3
iv	by modification of starch		4

* Question 7 = Question 9 for group 2
Question 7 & 8 - not included for group 1

SECTION C/3: Problems with respect to fat limitation in the diet

Indicate your opinion with regard to the following statements by marking either 1, 2, 3, 4 or 5 with a cross, where the different numbers represent the following:

1 = strongly agree
2 = agree
3 = uncertain
4 = do not really agree
5 = strongly disagree

		1	2	3	4	5	For office use only
1.	It is easy to convince patients to reduce their fat intake.						
2.	Patients find it difficult to follow a low-fat diet (30% or less) over an extended period of time						
3.	The lack of low-fat products makes it difficult to follow a low-fat diet.						
4.	Individuals are easily motivated to lose weight by limiting the fat in their diet.						
5.	Fat-limitation in the diet does not make the diet unpalatable.						
6.	Fat limited diets are not expensive.						
7.	Low-fat products are unpalatable.						
8.	The advantageous effect of low-fat products will be cancelled by the fact that people will then eat more of the product.						
9.	Members of the general public are willing to use low-fat products.						
10	Few low-fat products are commercially available.						

*** You will now be supplied with information regarding Simplesse, after which you are requested to evaluate three muffins as indicated in section D.**

SECTION D/4

SENSORY EVALUATION OF THE ACCEPTABILITY OF MUFFINS WITH RESPECT TO VARIOUS CRITERIA

- **Evaluate the acceptability of the muffins (in the specified order) with respect to the given criteria by marking the appropriate square with a cross.**

		EXTENT OF ACCEPTABILITY					Office use	
Criteria	Sample codes	5 Extremely acceptable	4 Acceptable	3 Neutral	2 Not acceptable	1 Extremely unacceptable	Code	
General appearance	1							
	2							
	3							
Colour	1							
	2							
	3							
Texture	1							
	2							
	3							
Flavour	1							
	2							
	3							

- **You have now evaluated both samples for acceptability according to certain criteria**

	Yes	No	
Is one of the samples more acceptable in total?			
If yes, which one? Write the code in the square.			

- **Please indicate how often you will be willing to eat the muffins. Choose only one option under each code.**

		Sample code		
		305	978	510
5. I will eat it every day.	5			
4. I will eat it often (1x/week).	4			
3. I will eat it occasionally (1x/month).	3			
2. I will only eat it when no other food is available.	2			
1. I will never eat it.	1			

Codes		
305	978	510

SECTION E/5

Indicate your opinion with regard to the following statements, by marking either 1, 2, 3, 4 or 5 with a cross, where the different numbers represent the following:

1 = strongly agree
2 = agree
3 = uncertain
4 = do not really agree
5 = strongly disagree

							For office use only
1.	The use of products containing ***Simplesse*** is not beneficial to one's health.	1	2	3	4	5	
2.	I will use products containing ***Simplesse*** in fat-limited diets.	1	2	3	4	5	
3.	Excessive fat intake is not detrimental to one's health.	1	2	3	4	5	
4.	An advantage of ***Simplesse*** is that it only substitutes the fat in the product and does not change the macro-nutrient composition significantly.	1	2	3	4	5	
5.	There is no need for fat substitutes to replace fat in the diet.	1	2	3	4	5	
6.	The general public will not use food products which contain fat substitutes.	1	2	3	4	5	
7.	I favour ***Simplesse*** because it is not a synthetic product.	1	2	3	4	5	
8.	***Simplesse*** can be used as a beneficial contribution to the control of diabetes mellitus.	1	2	3	4	5	
9.	If available, I will recommend the use of products containing ***Simplesse.***	1	2	3	4	5	

* E10 was not included for group 1

SECTION F/6

Indicate your opinion with regard to the following statements by marking either 1, 2, 3, 4 or 5 with a cross where the different numbers represent the following:

1 = strongly agree
2 = agree
3 = uncertain
4 = disagree
5 = strongly disagree

							For office use only
1.	Fat substitutes such as ***Simplesse*** should be used in food products where fat limitation in the diet is needed.	1	2	3	4	5	
2.	Fat limitation of up to 30% or less of the total energy i ntake of the diet is facilitated by using fat substitutes.	1	2	3	4	5	
3.	***Simplesse*** reduces the general acceptability of products.	1	2	3	4	5	
4.	The use of fat substitutes in food products does not provide exceptional advantages.	1	2	3	4	5	
5.	Fat substitutes do not contribute to a tasty low-fat diet.	1	2	3	4	5	
6.	Products containing ***Simplesse*** can be used success-fully in slimming diets.	1	2	3	4	5	
7.	The use of ***Simplesse*** does not offer advantages for a prudent diet.	1	2	3	4	5	
8.	The availability of ice cream containing ***Simplesse*** facilitates the planning of low-fat diets.	1	2	3	4	5	

Thank you very much for your co-operation.

* 9 & 10 were not included for group 1.

VRAELYS VIR DIEETKUNDIGES: STRENG VERTROULIK (GROEP 1)

VRAELYS NO. | | | |

*** Merk die toepaslike blok met 'n kruisie (X)**

AFDELING A/I
DEMOGRAFIESE GEGEWENS

1. GESLAG

Slegs vir kantoor-gebruik

Manlik	1
Vroulik	2

2. BEROEP

Kliniese dieetkundige	1
Administratiewe dieetkundige	2
Gemeenskapsdieetkundige	3
Dieetkundige - ander	4

3. OUDERDOM

Tussen 21 en 30 jaar	1
Tussen 31 en 40 jaar	2
Ouer as 40 jaar	3

4. JAAR AFGESTUDEER

Voor 1960	1
Tussen 1961-1970	2
Tussen 1971-1980	3
Tussen 1981-1990	4
Na 1990	5

KENNIS- EN HOUDINGSVRAELYS: *SIMPLESSE*

AFDELING B/2: Kennis/bewustheid aangaande vetvervangers byvoorbeeld *Simplesse.*

Beantwoord die volgende vrae deur 'n kruisie in die toepaslike blokkie te maak (X)

		Ja	Nee	Slegs vir kantoor-gebruik
1.	Het u voor hierdie byeenkoms reeds van vetvervangers kennis gedra?			
2.	Het u voor hierdie byeenkoms reeds van Simplesse spesifiek kennis gedra?			
3.	Verlaag vetvervangers die energiewaarde van produkte?			
4.	Is ***Simplesse*** veilig om te gebruik?			
5.	Word daar tans enige navorsing oor die fisiologiese effekte van ***Simplesse*** as vetvervanger gedoen?			
6.	Is u bewus van navorsing oor die gebruik van vetvervangers in produkontwikkeling?			

7* Hoe word ***Simplesse*** berei?

i	gesuiwerde sellulose-derivate	1	
ii	mikroverdeling van melk-/eierwitproteïen	2	
iii	estrifisering van sukrose en vetsure	3	
iv	modifiëring van stysel	4	

* Vraag 7 = Vraag 9 vir groep 2
Vraag 7 & 8 ontbreek vir groep 1

AFDELING C/3: Probleme ten opsigte van vetbeperking in die dieet

Dui u mening met betrekking tot die volgende bewerings/stellings aan deur net 'n kruisie in blokkie 1, 2, 3, 4 of 5 te maak, waar die blokkies die volgende mening verteenwoordig:

1 = stem volkome saam (volkome instemmend)
2 = stem saam (instemmend)
3 = onseker
4 = stem nie eintlik saam nie (effens afkeurend)
5 = stem glad nie saam nie (sterk afkeurend)

		Slegs vir kantoor-gebruik
1.	Dit is maklik om pasiënte te oortuig om minder vet deur hul dieet in te neem.	1 2 3 4 5
2.	Pasiënte vind dit moeilik om oor die langtermyn 'n laevetdieet (30% of minder) getrou te volg.	1 2 3 4 5
3.	Die gebrek aan laevetprodukte maak dit moeilik om 'n laevetdieet te volg.	1 2 3 4 5
4.	Mense word maklik gemotiveer om deur vetbeperking in die dieet gewig te verloor.	1 2 3 4 5
5.	Beperking van vet in die dieet maak nie die dieet onsmaaklik nie.	1 2 3 4 5
6.	Vetbeperkte diëte is nie duur nie.	1 2 3 4 5
7.	Laevetprodukte is onsmaaklik.	1 2 3 4 5
8.	Die voordelige effek van laevetprodukte sal gekanselleer word deurdat mense dan meer van die produk sal eet.	1 2 3 4 5
9.	Die algemene publiek is gewillig om laevetprodukte te gebruik.	1 2 3 4 5
10	Daar is min laevetprodukte kommersieel beskikbaar.	1 2 3 4 5

*** Inligting oor *Simplesse* word vervolgens aan u verskaf en daarna word u versoek om drie muffins te evalueer soos aangedui in Afdeling D.**

AFDELING D/4

SINTUIGLIKE EVALUERING VAN DIE AANVAARBAARHEID VAN MUFFINS TEN OPSIGTE VAN VERSKILLENDE KRITERIA

- **Evalueer die aanvaarbaarheid van die muffins (in volgorde soos aangedui) ten opsigte van genoemde kriteria deur 'n kruisie in die toepaslike blokkie te maak.**

		MATE VAN AANVAARBAARHEID				
Kriteria	Monster-kodes	5 Besonder aanvaarbaar	4 Aanvaar-baar	3 Neutraal	2 Nie aan-vaarbaar	1 Glad nie aanvaarbaar
Voorkoms	1					
	2					
	3					
Kleur	1					
	2					
	3					
Tekstuur	1					
	2					
	3					
Smaak	1					
	2					
	3					

Kantoorgebruik

Kode	

- **U het nou al die monsters vir aanvaarbaarheid volgens sekere kriteria geëvalueer.**

	Ja (1)	Nee (2)	
Is een van die monsters vir u in totaal meer aanvaarbaar?			
Indien Ja, watter een? Skryf kode in blokkie in.			

- **Dui asseblief aan hoe dikwels u bereid sal wees om die muffins te eet. Merk slegs een blokkie teenoor elke monsterkode**

		Monsterkode		
		305	978	510
5. Ek sal dit elke dag eet.	5			
4. Ek sal dit dikwels eet (1x/week).	4			
3. Ek sal dit af en toe eet (1x/maand).	3			
2. Ek sal dit slegs eet indien daar geen ander voedsel beskikbaar is nie.	2			
1. Ek sal dit nooit eet nie.	1			

Kodes

305	978	510

AFDELING E/5

Dui u mening met betrekking tot die volgende bewerings/stellings aan deur net 'n kruisie in blokkie 1, 2, 3, 4 of 5 te maak, waar die blokkies die volgende mening verteenwoordig:

1 = stem volkome saam (volkome instemmend)
2 = stem saam (instemmend)
3 = onseker
4 = stem nie eintlik saam nie (effens afkeurend)
5 = stem glad nie saam nie (sterk afkeurend)

							Slegs vir kantoor-gebruik
1.	Die gebruik van produkte wat ***Simplesse*** bevat, hou nie gesondheidsvoordele in nie.	1	2	3	4	5	
2.	Ek sal produkte wat ***Simplesse*** bevat in vetbeperkte diëte gebruik.	1	2	3	4	5	
3.	Oormatige inname van vet is nie nadelig vir die mens se gesondheid nie.	1	2	3	4	5	
4.	'n Voordeel van ***Simplesse*** is dat dit slegs die vet in die produk vervang en nie die makronutriëntsamestelling betekenisvol verander nie.	1	2	3	4	5	
5.	Daar is nie 'n behoefte aan vetvervangers as substituut vir vet in die dieet nie.	1	2	3	4	5	
6.	Die algemene publiek sal nie voedselprodukte wat vetvervangers bevat, gebruik nie.	1	2	3	4	5	
7.	Ek hou van ***Simplesse*** omdat dit nie 'n sintetiese produk is nie.	1	2	3	4	5	
8.	Die gebruik van ***Simplesse*** kan 'n voordelige bydrae lewer tot die kontrole van diabetes mellitus.	1	2	3	4	5	
9.	Ek sal die gebruik van produkte wat ***Simplesse*** bevat, aanbeveel indien dit beskikbaar is.	1	2	3	4	5	

* E10 ontbreek vir groep 1

AFDELING F/6

Dui u mening met betrekking tot die volgende bewerings/stellings aan deur net 'n kruisie in blokkie 1, 2, 3, 4 of 5 te maak, waar die blokkies die volgende mening verteenwoordig:

1 = stem volkome saam (volkome instemmend)
2 = stem saam (instemmend)
3 = onseker
4 = stem nie eintlik saam nie (effens afkeurend)
5 = stem glad nie saam nie (sterk afkeurend)

							Slegs vir kantoor-gebruik
1.	Vetvervangers bv. ***Simplesse*** moet in voedsel-produkte gebruik word waar vetbeperking in die dieet nodig is.	1	2	3	4	5	
2.	Vetbeperking in die dieet tot 30% of minder van die totale energie-inname word deur die gebruik van vetvervangers vergemaklik.	1	2	3	4	5	
3.	***Simplesse*** verminder die algemene aanvaarbaar-heid van produkte.	1	2	3	4	5	
4.	Die gebruik van vetvervangers in voedselprodukte hou nie besondere voordele in nie.	1	2	3	4	5	
5.	Vetvervangers lewer nie 'n bydrae tot 'n smaaklike laevet dieet nie.	1	2	3	4	5	
6.	Produkte met ***Simplesse*** kan met sukses in ver-slankingsdiëte gebruik word.	1	2	3	4	5	
7.	Die gebruik van ***Simplesse*** hou nie voordele vir 'n normale dieet in nie.	1	2	3	4	5	
8.	Die beskikbaarheid van roomys met ***Simplesse*** ver gemaklik die beplanning van laevetdiëte.	1	2	3	4	5	

* E9&10 ontbreek vir groep 1

Baie dankie vir u samewerking.

QUESTIONNAIRE FOR DIETITIANS: STRICTLY CONFIDENTIAL (GROUP 2)

QUESTIONNAIRE NO. | | | |

*** Mark the appropriate square with a cross (X)**

SECTION A/I

DEMOGRAPHIC INFORMATION

1. SEX

For office use only

Male	1
Female	2

2. CAREER

Clinical dietitian	1
Administrative dietitian	2
Community dietitian	3
Dietitian - other	4

3. AGE

Between 21 and 30 years	1
Between 31 and 40 years	2
Older than 40 years	3

4. DATE OF COMPLETION OF STUDIES

Before 1960	1
Between 1961-1970	2
Between 1971-1980	3
Between 1981-1990	4
After 1990	5

5. How often are you dieting to lose weight?

never	1	
rarely	2	
sometimes	3	
often	4	
always	5	

6.	**If you diet to lose weight, do you**		**Yes**	**No**	
6.1	fast	1			
6.2	skip meals	2			
6.3	avoid starches	3			
6.4	avoid sugars	4			
6.5	avoid fats	5			
6.6	eat smaller portions of everything	6			
6.7	exercise	7			

7.	**Do you regularly consume reduced kilojoule foods?**	**Yes**	**No**	

8.	**If yes, do you consume**		**Yes**	**No**	
8.1	diet beverages	1			
8.2	low-fat dairy products	2			
8.3	sugar-free products	3			
8.4	fat-free products	4			
8.5	low-fat food products	5			
8.6	others (please name) ----------	6			

KNOWLEDGE AND ATTITUDE QUESTIONNAIRE: *SIMPLESSE*

SECTION B/2: Knowledge/awareness regarding fat substitutes such as *Simplesse.*

Answer the following questions by marking the appropriate square with a cross (X)

		Yes	No	For office use only
1.	Did you have knowledge of fat substitutes before this meeting?			
2.	Did you have knowledge of *Simplesse* specifically before this meeting?			
3.	Do fat substitutes reduce the energy content of foods?			
4.	Is *Simplesse* safe to use?			
5.	Has any research been done on the physiological effects of *Simplesse* as a fat substitute?			
6.	Are you aware of research about the use of fat substitutes in product development?			
7.*	Does fat replacement in products have more advantages than eating smaller portions of full fat products?			
8.*	Are strict limitations of fat in your diet really necessary to prevent heart disease if you do not have a family history of heart disease?			

9. How is *Simplesse* made?

by purifying cellulose derivatives		1
by microparticulation of milk/egg white protein		2
by esterification of sucrose and fatty acids		3
by modification of starch		4

* Additional for group 2

SECTION C/3: Problems with respect to fat limitation in the diet

Indicate your opinion with regard to the following statements by marking either 1, 2, 3, 4 or 5 with a cross, where the different numbers represent the following:

1 = strongly agree
2 = agree
3 = uncertain
4 = disagree
5 = strongly disagree

			For office use only
1.	It is easy to convince patients to reduce their fat intake.	1 2 3 4 5	
2.	Patients find it difficult to follow a low-fat diet (30% or less) over an extended period of time	1 2 3 4 5	
3.	The lack of low-fat products makes it difficult to follow a low-fat diet.	1 2 3 4 5	
4.	Individuals are easily motivated to lose weight by limiting the fat in their diet.	1 2 3 4 5	
5.	Reducing dietary fat does not make the diet unpalatable.	1 2 3 4 5	
6.	Low-fat limited diets are not expensive.	1 2 3 4 5	
7.	Low-fat products are unpalatable.	1 2 3 4 5	
8.	The advantageous effect of low-fat products will be cancelled by the fact that people will then eat more of the product.	1 2 3 4 5	
9.	Members of the general public are willing to use low-fat products.	1 2 3 4 5	
10	Few low-fat products are commercially available.	1 2 3 4 5	

- **You will now be supplied with information regarding Simplesse, after which you are requested to evaluate three muffins as indicated in section D.**

SECTION D/4

SENSORY EVALUATION OF THE ACCEPTABILITY OF MUFFINS WITH RESPECT TO VARIOUS CRITERIA

- **Evaluate the acceptability of the muffins (in the specified order) with respect to the given criteria by marking the appropriate square with a cross.**

		EXTENT OF ACCEPTABILITY					Office use	
Criteria	Sample codes	5 Extremely acceptable	4 Acceptable	3 Neutral	2 Not acceptable	1 Extremely unacceptable	Code	
General appearance	1							
	2							
	3							
Colour	1							
	2							
	3							
Texture	1							
	2							
	3							
Flavour	1							
	2							
	3							

- **You have now evaluated the samples for acceptability according to certain criteria**

	Yes	No	
Is one of the samples more acceptable in total?			
If yes, which one? Write the code in the square.			

- **Please indicate how often you will be willing to eat the muffins. Choose only one option under each code.**

		Sample code		
		305	978	510
5. I will eat it every day.	5			
4. I will eat it often (1x/week).	4			
3. I will eat it occasionally (1x/month).	3			
2. I will only eat it when no other food is available.	2			
1. I will never eat it.	1			

Codes

305	978	510

SECTION E/5

Indicate your opinion with regard to the following statements by marking either 1, 2, 3, 4 or 5 with a cross, where the different numbers represent the following:

1 = strongly agree
2 = agree
3 = uncertain
4 = disagree
5 = strongly disagree

							For office use only
1.	The use of products containing ***Simplesse*** is not beneficial to one's health.	1	2	3	4	5	
2.	I will use products containing ***Simplesse*** in fat-limited diets.	1	2	3	4	5	
3.	Excessive fat intake is not detrimental to one's health.	1	2	3	4	5	
4.	An advantage of ***Simplesse*** is that it only sub stitutes the fat in the product and does not change the macro-nutrient composition significantly.	1	2	3	4	5	
5.	There is no need for fat substitutes to replace fat in the diet.	1	2	3	4	5	
6.	The general public will not use food products which contain fat substitutes.	1	2	3	4	5	
7.	I favour ***Simplesse*** because it is not a synthetic product.	1	2	3	4	5	
8.	***Simplesse*** can be used as a beneficial contribution to the control of diabetes mellitus.	1	2	3	4	5	
9.	If available, I will recommend the use of products containing ***Simplesse.***	1	2	3	4	5	
10.*	The availability of low-fat products containing fat substitutes will increase the variety of food for selection in the prudent diet.	1	2	3	4	5	

* Additional for group 2

SECTION F/6

Indicate your opinion with regard to the following statements by marking either 1, 2, 3, 4 or 5 with a cross where the different numbers represent the following:

1 = strongly agree
2 = agree
3 = uncertain
4 = disagree
5 = strongly disagree

							For office use only
1.	Fat substitutes such as ***Simplesse*** should be used in food products where fat limitation in the diet is needed.	1	2	3	4	5	
2.	Fat limitation of up to 30% or less of the total energy intake of the diet is facilitated by using fat substitutes.	1	2	3	4	5	
3.	***Simplesse*** reduces the general acceptability of products.	1	2	3	4	5	
4.	The use of fat substitutes in food products does not provide exceptional advantages.	1	2	3	4	5	
5.	Fat substitutes do not contribute to a tasty low-fat diet.	1	2	3	4	5	
6.	Products containing ***Simplesse*** can be used suc cessfully in slimming diets.	1	2	3	4	5	
7.	The use of ***Simplesse*** does not offer advantages for a prudent diet.	1	2	3	4	5	
8.	The availability of ice cream containing ***Sim plesse*** facilitates the planning of low-fat diets.	1	2	3	4	5	
9.*	A diet low in fat (30% or less) is the healthy trend of today.	1	2	3	4	5	
10.*	Diet is important in avoiding problems such as heart disease/cancer.	1	2	3	4	5	

* Additonal for group 2

Thank you very much for your co-operation.

ADDENDA REGARDING THE STUDY REPORTED IN CHAPTER 4

* Consumer questionnaire
* Verbruikersvraelys

CONSUMER QUESTIONNAIRE: STRICTLY CONFIDENTIAL

QUESTIONNAIRE NO. | | | |

*** Mark the appropriate square with a cross (X)**

SECTION A/I
DEMOGRAPHIC INFORMATION

1. SEX

For office use only

Male	1
Female	2

2. AGE

Between 21 and 30 years	1
Between 31 and 40 years	2
Older than 40 years	3

3. IN YOUR OPINION, YOU ARE

very underweight	1
underweight	2
about the right weight	3
overweight	4
very overweight	5

4. HOW OFTEN ARE YOU DIETING TO LOSE WEIGHT?

never	1
rarely	2
sometimes	3
often	4
always	5

			Yes	No	
5.	**IF YOU DIET TO LOSE WEIGHT, DO YOU**				
5.1	fast	1			
5.2	skip meals	2			
5.3	avoid starches	3			
5.4	avoid sugars	4			
5.5	avoid fats	5			
5.6	eat smaller portions of everything	6			
5.7	exercise physically	7			

	Yes	No	
6. DO YOU REGULARLY CONSUME REDUCED KILOJOULE FOODS?			

			Yes	No	
7.	**IF YES, DO YOU CONSUME**				
7.1	diet beverages	1			
7.2	low-fat dairy products	2			
7.3	sugar-free products	3			
7.4	fat-free products	4			
7.5	low-fat food products	5			
7.6	others (please name).....	6			

.....

SECTION B

SENSORY EVALUATION OF THE ACCEPTABILITY OF MUFFINS WITH RESPECT TO VARIOUS CRITERIA

- **Evaluate the acceptability of the muffins (in the specified order) with respect to the given criteria by marking the appropriate square with a cross.**

		EXTENT OF ACCEPTABILITY				
Criteria	Sample codes	5 Extremely acceptable	4 Acceptable	3 Neutral	2 Not acceptable	1 Extremely unacceptable
General appearance	1					
	2					
	3					
Colour	1					
	2					
	3					
Texture	1					
	2					
	3					
Flavour	1					
	2					
	3					

Office use

Code	

- **You have now evaluated both samples for acceptability according to certain criteria**

	Yes	No	
Is one of the samples more acceptable in total?			
If yes, which one? Write the code in the square.			

- **Please indicate how often you will be willing to eat the muffins. Choose only one option under each code.**

		Sample code		
		305	978	510
5. I will eat it every day.	5			
4. I will eat it often (1x/week).	4			
3. I will eat it occasionally (1x/month).	3			
2. I will only eat it when no other food is available.	2			
1. I will never eat it.	1			

Codes

305	978	510

VERBRUIKERSVRAELYS: STRENG VERTROULIK

VRAELYSNO. | | | |

*** Merk die toepaslike blok met 'n kruisie (X)**

AFDELING A
DEMOGRAFIESE GEGEWENS

1. GESLAG

Slegs vir kantoor-gebruik

Manlik	1
Vroulik	2

2. OUDERDOM

Tussen 21 and 30 jaar	1
Tussen 31 and 40 jaar	2
Ouer as 40 jaar	3

3. VOLGENS U MENING, IS U

baie ondergewig	1
ondergewig	2
omtrent die regte gewig	3
oorgewig	4
baie oorgewig	5

4. HOE DIKWELS VOLG U 'N VERSLANKINGSDIEET?

nooit	1
selde	2
soms	3
dikwels	4
altyd	5

			Ja	Nee	
5.	**INDIEN U WIL VERSLANK, WAT DOEN U**				
5.1	vas	1			
5.2	slaan etes oor	2			
5.3	vermy stysel	3			
5.4	vermy suiker	4			
5.5	vermy vet	5			
5.6	eet kleiner porsies van alles	6			
5.7	liggaamsbeweging/-oefening	7			

		Ja	Nee	
6.	**EET/DRINK U DIKWELS VOEDSELPRODUKTE MET 'N VERLAAGDE KILOJOULEWAARDE?**			

			Ja	Nee	
7.	**INDIEN JA, WATTER VAN DIE VOLGENDE?**				
7.1	dieetkoeldranke	1			
7.2	lae-vet melkprodukte	2			
7.3	suikervrye produkte	3			
7.4	vetvrye produkte	4			
7.5	lae-vet produkte	5			
7.6	ander, noem	6			

.....

AFDELING B

SINTUIGLIKE EVALUERING VAN DIE AANVAARBAARHEID VAN MUFFINS TEN OPSIGTE VAN VERSKILLENDE KRITERIA

- **Evalueer die aanvaarbaarheid van die muffins (in volgorde soos aangedui) ten opsigte van genoemde kriteria deur 'n kruisie in die toepaslike blokkie te maak.**

		MATE VAN AANVAARBAARHEID				
Kriteria	Monster kodes	5 Besonder aanvaarbaar	4 Aanvaar-baar	3 Neutraal	2 Nie aan-vaarbaar	1 Glad nie aanvaarbaar
Voorkoms	1					
	2					
	3					
Kleur	1					
	2					
	3					
Tekstuur	1					
	2					
	3					
Smaak	1					
	2					
	3					

Kantoorgebruik

Kode	

- **U het nou al die monsters vir aanvaarbaarheid volgens sekere kriteria geëvalueer.**

	Ja	Nee	
Is een van die monsters vir u in totaal meer aanvaarbaar?			
Indien Ja, watter een? Skryf kode in blokkie in.			

- **Dui asseblief aan hoe dikwels u bereid sal wees om die muffins te eet. Merk slegs een blokkie teenoor elke monsterkode.**

		Monsterkode		
		305	978	510
5. Ek sal dit elke dag eet.	5			
4. Ek sal dit dikwels eet (1x/week).	4			
3. Ek sal dit af en toe eet (1x/maand).	3			
2. Ek sal dit slegs eet indien daar geen ander voedsel beskikbaar is nie.	2			
1. Ek sal dit nooit eet nie.	1			

Kodes

305	978	510

ADDENDA REGARDING SENSORY EVALUATION REPORTED IN CHAPTERS 5 AND 6

* Sintuiglike evalueringsvorm: muffinprojekte 4 & 5
* Evalueringsvorm vir evaluering van nuutgedefinieerde en addisionele eienskappe (projekte 4 & 5)
* Sensory evaluation sheet: muffin projects 4 & 5
  (* Redefined and additional attributes which were evaluated afterwards)
* Table 2: Reliability coefficients (projects 4 & 5)

SINTUIGLIKE EVALUERINGSVORM: MUFFINPROJEK 4 & 5

EVALUEER DIE MONSTERS TEN OPSIGTE VAN GENOEMDE KRITERIA IN DIE VOLGORDE SOOS AANGEDUI. VUL TOEGEKENDE WAARDES (1-6) IN BETROKKE RUIMTES IN.

KRITERIA

['n Waarde van ses verteenwoordig die maksimum intensiteit en een die minimum relatief tot die definisie en skaaleindpunte vir elke eienskap gestel.]

Proepaneellidnommer				01
Sessienommer				02
Volgorde	1	2	3	03
Monsterkode				
Formule				04-06

1. VOORKOMS

1.1 Bokorsvorm
1 - Asimmetries/Oneweredig
6 - Simmetries, effens gerond, eweredig — 07

1.2 Korsglans
1 - Dof
6 - Glansend — 08

1.3 Korskleur
1 - Te lig/te donker bruin
6 - Donker goudbruin — 09

1.4 Korsoppervlak
1 - Glad
6 - Hobbelrig (blomkool) — 10

1.5 Kruimkleur
1 - Te lig/te donker bruin
6 - Donker goudbruin — 11

2. TEKSTUUR

2.1 Selverspreiding
1 - Oneweredig
6 - Eweredig — 12

2.2 Selgrootte
1 - Klein selle
6 - Groot selle — 13

	Volgorde	1	2	3	03
	Monsterkode				
	Formule				04-06
2.3	Saamdrukbaarheid 1 - Moeilik saamdrukbaar, ferm 6 - Maklik saamdrukbaar, sag				14
2.4	Korssagtheid 1 - Nie sag 6 - Sag				15
2.5	Krummelrigheid tydens eerste koufase 1 - Klewerig - kluitjierig en vas 6 - Krummelrig en los				16
2.6	Krummelrigheid na koufase 1 - Klewerig - vorm 'n bal 6 - Krummelrig en los				17
2.7	Kruimsagtheid 1 - Nie sag - ferm 6 - Sag				18
2.8	Klewerigheid van deeltjies aan tande (adhesie) 1 - Kleef aan tande vas 6 - Kleef nie aan tande vas nie				19
3.	**SMAAK**				
3.1	1 - Nie tipies (bysmaak/nasmaak) 6 - Tipies (neuterig, nie te soet)				20

Spesifiseer enige bysmaak of skerp/intense smaak of nasmaak

.....

.....

.....

BAIE DANKIE VIR U DEELNAME

SINTUIGLIKE EVALUERINGSVORM: MUFFINPROJEK 4 & 5

EVALUERINGSVORM VIR SINTUIGLIKE EVALUERING VAN NUUTGEDEFINIEERDE* EN ADDISIONELE# EIENSKAPPE (PROJEKTE 4 & 5)

KRITERIA

['n Waarde van ses verteenwoordig die maksimum intensiteit en een die minimum relatief tot die definisie en skaaleindpunte vir elke eienskap gestel.]

Proepaneellidnommer		01
Sessienommer		02
Volgorde	1 2 3	03
Monsterkode		
Formule		04-06

1. VOORKOMS

*1.3 Korskleurligtheid
1 - Donkerbruin
6 - Ligbruin — 07

*1.5 Kruimkleurligtheid
1 - Donkerbruin
6 - Ligbruin — 08

2. TEKSTUUR

#2.9 Mondvoel - kruimvogtigheid
1 - Droog
6 - Klam — 09

3. SMAAK

#3.2 Soet
1 - Min soet
6 - Baie soet — 10

#3.3 Nie-spesifieke neuterige smaak
1 - Geen neuterige smaak
6 - Sterk neuterige smaak — 11

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SENSORY EVALUATION SHEET: MUFFIN PROJECT 4 & 5

EVALUATE THE SAMPLES IN THE SPECIFIED ORDER WITH RESPECT TO THE GIVEN CRITERIA. WRITE THE RATING (1-6) IN THE APPROPRIATE BLOCKS

CRITERIA

[A rating of six is the maximum intensity and one the minimum relative to the definition and scale anchors set for each attribute.]

Panelist's number				01
Session				02
Order	1	2	3	03
Sample code				
Formula				04-06

1. APPEARANCE

1.1 Top crust shape (symmetry or evenness)
1 - Asymmetrical/Uneven
6 - Symmetrical, slightly rounded/even

1.2 Crust gloss
1 - Dull
6 - Glossy

1.3 Crust colour lightness
1 - Dark brown
6 - Light (golden) brown

1.4 Crust surface roughness
1 - Smooth
6 - Coarse (pebbled)

1.5 Crumb colour lightness
1 - Dark brown
6 - Light (golden) brown

2. TEXTURE

2.1 Cell distribution (evenness)
1 - Uneven
6 - Even

2.2 Cell size
1 - Small cells
6 - Large cells

			07
			08
			09
			10
			11
			12
			13

	Order	1	2	3	03
	Sample code				
	Formula				04-06
2.3	Compressibility 1 - Not easily compressed, firm 6 - Easily compressed, not firm				14
2.4	Crust tenderness 1 - Not tender 6 - Tender				15
2.5	Mouthfeel - crumb moistness perceived 1 - Dry 6 - Moist				16
2.6	Crumbliness at initial bite 1 - Cohesive - clumped together 6 - Crumbly and loose				17
2.7	Crumbliness of mass after chewing 1 - Cohesive - clumped together, ball-like mass 6 - Crumbly and loose				18
2.8	Crumb tenderness 1 - Not tender 6 - Tender				19
2.9	Adhesiveness (toothpacking) after chewing 1 - Sticks to the teeth (adhesive) 6 - Does not stick to the teeth (not adhesive)				20
3.	**FLAVOUR**				
3.1	1 - Atypical (taint/aftertaste) 6 - Typical without any taints Specify any taint or aftertaste, if present.				21
3.2	Sweet (fundamental taste factor) 1 - Weak sensation/not sweet 6 - Strong sensation/very sweet				22
3.3	Non-specific nut-like aromatic note 1 - No nutty flavour 6 - Strong nutty flavour.				23

THANK YOU FOR YOUR PARTICIPATION

TABLE 2: Reliability coefficients of the sensory panel and individual panellists for different sensory attributes (Project 4 & 5)

Criteria	Panel	Panellist 1	Panellist 2	Panellist 3	Panellist 4	Panellist 5	Panellist 6	Panellist 7	Panellist 8
1. Appearance									
1.1 Top crust shape	0.9961	0.9803	0.9771	0.9600	0.9873	0.9312	0.9727	0.9600	0.9806
1.2 Crust gloss	0.9671	0.8859	0.9500	0.8333	0.8889	0.7407	0.7407	0.6666	0.8889
1.3 Crust colour lightness	0.9957	0.9932	0.9796	0.9796	0.8980	0.9783	0.9630	0.9898	0.9600
1.4 Crust surface	0.9968	0.9866	0.9841	0.9913	0.9841	0.9306	0.9913	0.9606	0.9913
1.5 Crumb colour lightness	0.9938	0.9998	0.9524	0.9867	0.9998	0.8815	0.9676	0.9796	0.9630
2. Texture									
2.1 Cell distribution	0.9966	0.9681	0.9841	0.9956	0.9306	0.9623	0.9839	0.9841	0.9913
2.2 Cell size	0.9967	0.9681	0.9913	0.9912	0.9030	0.9371	0.9956	0.9898	0.9873
2.3 Compressibility	0.9964	0.9998	0.9998	0.9829	0.9873	0.9330	0.9778	0.9839	0.9762
2.4 Crust tenderness	0.9893	0.8889	1.0000	0.6666	0.9600	0.9600	0.9600	0.8889	0.6666
2.5 Crumbliness (initial bite)	0.9912	0.8889	0.6666	1.0000	0.9600	0.8750	0.9600	1.0000	0.8889
2.6 Crumbliness (after chewing)	0.9868	0.8889	0.6666	0.6666	1.0000	0.7407	1.0000	0.9600	1.0000
2.7 Crumb tenderness	0.9930	0.9600	0.9603	0.9841	0.9371	0.8000	0.9286	0.9781	0.9800
2.8 Adhesiveness	0.9761	0.6666	0.8750	0.8750	0.8333	0.8750	0.7407	0.8750	0.5926
3. Flavour	0.9989	0.9998	0.9998	0.9998	0.9867	0.9445	0.9998	0.9965	0.9879

ADDENDA REGARDING ASSIGNING, CODING AND ORDER OF PRESENTATION OF SAMPLES

* Assigning and coding of samples (projects 4 & 5)
* Order of presentation of samples (projects 4 & 5)

ASSIGNING AND CODING OF SAMPLES PER SESSION DURING FINAL PROJECTS 4 & 5 - SENSORY, PHYSICAL AND MICROBIAL ANALYSES

	Session 1		Session 2		Session 3		Session 4		Session 5		Session 6		Session 7		Session 8		Session 9		Session 10	
Order of presentation	Treat-ment	Sample code	Treat-ment	Sample code	Treat-ment	Sample code	Treat-ment	Sample code	Treat-ment	Sample code	Treat-ment	Sample code	Treat-ment	Sample code	Treat-ment	Sample code	Treat-ment	Sample code	Treat-ment	Sample code
Series 1																				
1	1*R	ckd	1*R	ucf	1@R	mjc	1*#	klm	1*$	kdr	1*$	jnb	1@R	ksy	1*R	dxv	1*$	exv	1*R	cvr
2	2*R	rpk	2*R	pts	2@R	vsk	2*#	djx	2*$	fjd	2*$	bme	2@R	dvb	2*R	bmx	2*$	lrs	2*R	nsl
3	3*R	afg	3*R	dcp	3@R	bjx	3*#	cmt	3*$	hkm	3*$	avz	3@R	jts	3*R	epr	3*$	zst	3*R	lgn
Series 2																				
1	1@R	fsl	1*$	hmd	1fR	nrs	1fR	bts	1*#	fyk	1fR	crs	1*#	qxr	1*#	sfj	1@R	mbc	1fR	brz
2	2@R	phf	2*$	xvs	2fR	pqk	2fR	ctk	2*#	hms	2fR	pje	2*#	rcb	2*#	ghr	2@R	odt	2fR	drp
3	3@R	gls	3*$	jns	3fR	rtz	3fR	nts	3*#	rce	3fR	skd	3*#	dgh	3*#	msk	3@R	msl	3fR	jfr

Formula	1	2	3
Muffin shelf-life	2 hours = * freshly baked	26 hours = @	14 days frozen/ thawed = f
Batter age refrigerated before baking	fresh = R	24 hours = #	48 hours = $

Shelf-life:

* = Muffin: served freshly baked; freshly prepared batter
@ = Muffin: served 24 hours after baking freshly prepared batter
f = Muffin: served after being frozen for 14 days and thawed; freshly prepared batter

Batter age:

R = Freshly prepared batter - served freshly baked
# = Batter refrigerated 24 hours - served freshly baked
$ = Batter refrigerated 48 hours - served freshly baked

6 (2X3) SAMPLE, 4 REPLICATION, INCOMPLETE BALANCED-BLOCK DESIGN (SENSORY ANALYSIS)

ORDER OF PRESENTATION OF SAMPLES										
PANELLIST	Session 1 Series 1	Session 2 Series 1	Session 3 Series 1	Session 4 Series 1	Session 5 Series 1	Session 6 Series 1	Session 7 Series 1	Session 8 Series 1	Session 9 Series 1	Session 10 Series 1
1	3 1 2	1 2 3	2 3 1	2 1 3	3 2 1	1 3 2	3 1 2	1 2 3	2 3 1	2 1 3
2	2 1 3	3 2 1	1 3 2	1 2 3	2 3 1	3 1 2	2 1 3	3 2 1	1 3 2	1 2 3
3	1 2 3	2 3 1	3 1 2	3 2 1	1 3 2	2 1 3	1 2 3	2 3 1	3 1 2	3 2 1
4	3 2 1	1 3 2	2 1 3	2 3 1	3 1 2	1 2 3	3 2 1	1 3 2	2 1 3	2 3 1
5	2 3 1	3 1 2	1 2 3	1 3 2	2 1 3	3 2 1	2 3 1	3 1 2	1 2 3	1 3 2
6	1 3 2	2 1 3	3 2 1	3 1 2	1 2 3	2 3 1	1 3 2	2 1 3	3 2 1	3 1 2
7	3 1 2	1 2 3	2 3 1	2 1 3	3 2 1	1 3 2	3 1 2	1 2 3	2 3 1	2 1 3
8	2 1 3	3 2 1	1 3 2	1 2 3	2 3 1	3 1 2	2 1 3	3 2 1	1 3 2	1 2 3
	Session 1 Series 2	Session 2 Series 2	Session 3 Series 2	Session 4 Series 2	Session 5 Series 2	Session 6 Series 2	Session 7 Series 2	Session 8 Series 2	Session 9 Series 2	Session 10 Series 2
1	2 1 3	3 2 1	1 3 2	3 1 2	1 2 3	2 3 1	2 1 3	3 2 1	1 3 2	3 1 2
2	1 2 3	2 3 1	3 1 2	2 1 3	3 2 1	1 3 2	1 2 3	2 3 1	3 1 2	2 1 3
3	3 2 1	1 3 2	2 1 3	1 2 3	2 3 1	3 1 2	3 2 1	1 3 2	2 1 3	1 2 3
4	2 3 1	3 1 2	1 2 3	3 2 1	1 3 2	2 1 3	2 3 1	3 1 2	1 2 3	3 2 1
5	1 3 2	2 1 3	3 2 1	2 3 1	3 1 2	1 2 3	1 3 2	2 1 3	3 2 1	2 3 1
6	3 1 2	1 2 3	2 3 1	1 3 2	2 1 3	3 2 1	3 1 2	1 2 3	2 3 1	1 3 2
7	2 1 3	3 2 1	1 3 2	3 1 2	1 2 3	2 3 1	2 1 3	3 2 1	1 3 2	3 1 2
8	1 2 3	2 3 1	3 1 2	2 1 3	3 2 1	1 3 2	1 2 3	2 3 1	3 1 2	2 1 3