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Microbiological, physico-chemical and sensory quality aspects of dairy desserts manufactured from cottage cheese

by

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I, the undersigned, hereby declare that this dissertation and the associated research comprises my own original work, except for assistance which is acknowledged. I also declare that the results contained in this dissertation have not been previously submitted by me in respect of a degree or diploma at any tertiary institution.

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ABSTRACT

Two novel strawberry cottage cheese desserts were developed in this study and evaluated regarding their microbiological, physico-chemical and sensory characteristics.

The purpose of the study was to develop cottage cheese desserts, both full-fat (FFCCD) and skim milk (SMCCD) from fresh cottage cheese. Four formulations were made by adding fruit pulp to the cottage cheese. These were; treatment 1 = 0 % fruit pulp, treatment 2 = 10 % fruit pulp, treatment 3 = 20 % fruit pulp and treatment 4 = 30 % fruit pulp.

All of the four treatments were found to be acceptable by a consumer panel and preference scale increased with an increase in the percentage fruit pulp added, texture and appearance. The microbiological status of the treatments was also at acceptable levels at the proposed shelf life of 21 days after which, spoilage microorganisms started to grow. The added fruit pulp increased their keeping quality by increasing the shelf life. The composition of the two

desserts types was also acceptable and compared well with results from other studies. It still remains that the fat content played a major role in distinguishing the two dessert types. The effect of the fat, fruit and fat/fruit interaction was evaluated. During shelf life studies, the effect of the fat, fruit, fat/fruit, day, day/fat, day/fruit as well as the day/fat/fruit interaction was also evaluated on the microbiological, pH and titratable acidity values of the treatments with a tendency to decrease by day with an increase in the percentage fruit added.

It could then be concluded that the addition of fruit pulp to the fresh cottage cheese increased its shelf life, acceptability and the new product serves as an alternative to fruit blended yogurts which exist in the market. The methods used could be adapted to a small scale and thus be part of food security programmes in South Africa. However, for the new product to partake in the dairy industry, it is recommended that the product be marketed properly.

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LIST OF ABBREVIATIONS

$AgNO_3$:	Silver Nitrate
AOAC:	Association of Official Analytical Chemists International
ARC:	Agricultural Research Council
a_w:	Water Activity
CHO:	Carbohydrate
CRD:	Completely Randomised Design
DVS:	Direct Vat Set
FFCC:	Full-fat cottage cheese
FFCCD:	Full-fat cottage cheese dessert
FFM:	Full-fat milk
FIDM:	Fat-in-dry-matter
HPLC:	High Pressure Liquid Chromatography
IDF:	International Dairy Federation
kJ:	kiloJoule
LAB:	Lactic acid bacteria
LSD:	Least significant difference
M/V:	Mass per volume
ME:	Milli equivalent
MIFF's:	Moisture in fat-free substances
NFS:	Non-fat solids
SIW:	Salt-in-water
SM:	Skim milk
SMCC:	Skim milk cottage cheese
SMCCD:	Skim milk cottage cheese dessert
TA:	Titratable acidity
TC:	Total carbohydrates
TCC:	Total colony count
UF:	Ultrafiltered

CHAPTER 1

INTRODUCTION

In Africa traditional cheesemaking is dictated by tradition and manufactured on a very small scale and depends on the availability of milk (O'Connor, 1993). These cheeses have a limited shelf life due to poor storage conditions, lack of refrigeration and infrastructure. However, their shelf life can be partially extended by immersing the cheese in a salt solution, dry salting, drying or even by smearing oil on the surface of the cheese.

South Africa has a low *per capita* consumption of milk and dairy products as compared to other countries which are affiliated to the International Dairy Federation (IDF, 2007). In South Africa, the consumption of milk and fermented milk products has been decreasing, from 148 000 metric tonnes in 2002, 66 000 metric tonnes in 2003 to an estimated, 69 000 metric tonnes in 2004 (IDF, 2007). Cheese production in this period remained almost stable with 48 000, 50 000 and 46 000 metric tonnes for the same years (IDF, 2007). It is estimated that the *per capita* consumption of cheese in South Africa has increased from 1 to 9 kg per year since 1995. According to CheeseSA (2008), an amount of 82 000 metric tonnes of cheese is locally produced from 800 million litres of milk. Of this, Cheddar and Gouda constitutes 51 % and Cream, Feta and Mozzarella cheeses account for 49 %. Feasibility studies conducted by the Sustainable Rural Livelihood Programme of the Agricultural Research Council (ARC), showed that this consumption is even lower in rural communities in South Africa as most people consume milk in its liquid form, either fresh or fermented (Anteneh, Mekala, Mnisi, Mukisira, Muthui, Murungweni and Sebitloane, 2004).

This study focused on the development of a dairy dessert manufactured from cottage cheese. Cottage cheese can be defined in many ways where the most commonly used one is that of it being a soft, fresh unripened cheese made from lactic acid curds and characterised by high moisture content, with a mild acidic flavour, smooth texture and short shelf life. Its texture could be smooth without the addition of rennet or chunky with renneted firmer curds (Shaw, 1986; Galloway, 1995; Scott, 1998; Kosikowski and Mistry, 1999a). This fresh cheese

is common in Central Europe where it originated from (called Tvarog or Turo), in Germany (Quarg) and France (Fromage Frais). It has a typical flavour of sour cream and upon consumption, it can be flavoured with spices, herbs or fruit. It is also used as an ingredient in recipes and salads (Jelen & Renz-Shauen, 1989).

1.1 PROBLEM STATEMENT

There is a growing demand for the development of safe, nutritious, affordable and accessible foods in South Africa and Africa at large to alleviate poverty and malnutrition (South Africa. Department of Agriculture Forestry and Fisheries (2008). Various programmes have been put in place by the Government to implement the proposed strategies on poverty alleviation. Thus, there is a need to develop new products and other food commodities of good quality nutrients which could have an impact on the daily dietary requirements of the young and old (South Africa. Department of Agriculture Forestry and Fisheries, 2008).

In the South African dairy industry, the manufacturing of dairy desserts from cottage cheese with added fruit pulps is minimal. According to Hermann (1996), cottage cheese is the most popular soft cheese produced locally but, however, as a savoury product it is available in a smooth or chunky texture, plain or with added savoury condiments such as ham, biltong, onions, chives, garlic and a variety of herbs. Little scientific information in terms of the chemical (proximate analysis), physico-chemical (pH, acidity), microbiological (shelf life) and sensory attributes of dairy desserts from cottage cheese is documented. Data collected during research and development within a specific industry is mostly confidential and patented. The quantity of added ingredients is controlled by the applicable legislation in different countries and products are graded in accordance with their sensory properties such as appearance, flavour and the overall consumer perception and acceptability (Mann, 1990; Hermann, 1996; Mann, 1997).

Since the study focuses on developmental aspects of food production and processing, there is an attempt to address skills transfer in most rural areas

within South Africa. Most of this milk is used for household consumption, is fresh or fermented (‘‘Maas/Amasi’’) and minimal processing is practiced. Therefore, it is deemed necessary to implement fundamental skills in such areas in the form of training in dairy processing techniques on a small scale. This will, in turn, enhance capacity amongst the rural communities as well as contributing to value adding to milk as an available raw material, and therefore possibly contribute to improved nutrition and poverty alleviation. The development of the dairy dessert is less labour intensive and does not require high inputs i.e. equipments used are those available within the household and these includes cooking utensils and any means of heating. The dessert could be regarded as an alternative to Amasi and yoghurt and yet high in protein content and other attributes inclusive of taste, nutritional quality, safety and cost effectiveness.

The main objective of the study is to develop an acceptable dairy dessert manufactured from cottage cheese.

1.2 OBJECTIVES

- To develop and evaluate a range of full-fat and skim-milk dairy desserts manufactured from cottage cheese, made from cow milk, with added fruit pulp at different concentrations, applying the Berge Process on a small scale. Full-fat and low-fat dairy deserts are herein referred to as full-fat cottage cheese dessert (FFCCD) and skim-milk cottage cheese dessert (SMCCD).
- To determine the chemical and physico-chemical properties (pH, acidity, protein, fat, ash and the moisture content), the cheese yield, the total carbohydrates and total energy values, the total solids content including salt and lactose, the microbiological shelf life and sensory properties of FFCCD and SMCCD.

CHAPTER 2

LITERATURE REVIEW

2.1 QUALITY ATTRIBUTES OF MILK USED IN CHEESEMAKING

2.1.1 Milk enzymology and microbiology

According to Varnam and Sutherland (1994), Kosikowski and Mistry (1999a) and Chambers (2002), milk is regarded as a highly perishable food commodity. Prior to cheesemaking, the quality of the milk must conform to certain set standards. Cheese milk may either be raw or pasteurised, hence cheeses made from such milks have different quality attributes. For example, if raw milk is used for cheesemaking it must be of a good quality with its microbial load at acceptable levels of 10^3/ml (Kosikowski and Mistry, 1999a).

Cheeses made from raw milk tend to have shorter ripening periods. This is due to the high levels of specific enzymes, indigenous to the milk (milk proteinases and lipases). In contrast, if pasteurised milk is used, the ripening period of the cheese is longer with less flavour development. For the production of fresh unripened cheeses such as cottage cheese, use of pasteurised milk is regarded as obligatory. This is due to the fact that these cheeses are consumed fresh and they do not undergo a ripening stage with all the subsequent biochemical reactions and the resultant inhibition of possible pathogens (Choisy, Desmazeaud, Gripon, Lamberet, Lenoir and Tourneur, 1986; Kosikowski and Mistry, 1999a).

According to Jay (2000), the most frequently occurring spoilage microbes in raw milk are from the genera *Enterococcus, Pseudomonas, Propionibacterium, Bacillus, Micrococcus, Microbacterium* as well as *E. coli* and coliforms which could occur due to poor hygienic practices. In stored pasteurised milk, spoilage is caused by the growth and metabolic activity of some psychrotrophs e.g. *Pseudomonas* spp as well as heat resistant organisms, such as *Bacillus*. In cheesemaking, these factors could have an adverse effect on the cheese flavour

due to fat hydrolysis as well as the cheese yield due to protein and fat losses (Hicks, Allauddi, Laggloi and O' Leary, 1982; Choisy *et al.* 1986).

Chambers (2002) reported that for raw milk, the bacterial load ranges between 10^3/ml when milk is of good quality and 10^7/ml when milk is of poor quality. Most of the microbes may be destroyed or inactivated by heat, prior to cheesemaking, except for some of their metabolites and enzymes which are heat resistant and which many still be present in the milk.

According to Chambers (2002), apart from the microbial load, milk quality may be affected by a variety of factors which include:

- seasonal and environmental factors which affect the milk composition indirectly by having an effect through the animal feed;
- the type of breed whereby the fat composition and the developed flavours will differ for the different animals;
- the initial milk composition when taking into consideration the ratio of fat to casein in the milk; and
- the presence of chemicals (sanitisers and preservatives), bacteriophages and antibiotics which might hinder the activity of the starter culture.

2.1.2 Milk composition

The typical composition of cow's milk is shown in Table 2.1 (Scott, 1998) and Table 2.2 showing comparison with data from South Africa (Smit, Smith & Schönfeldt, 1998a; Kosikowski and Mistry, 1999b). These milk components often determine the cheese quality and yield. The respective compositions of milk from different animal species that may either be cow or goat milk, will also differ. Skim milk has a fat content in the range of 0.1- 0.2 % when separated mechanically and between 0 and 1.75 % if it is skimmed by gravity. Cheeses made from skim milk will have higher protein contents than full-fat cheeses due to more solids-not-fat (SNF) components (Paz, Montero, Angulo and Garcia, 1998).

Table 2.1: Typical composition of cow's milk. Adapted from Scott, 1998.

Macro component	***Approximate composition***	***%***	***Micro components***
Fat	4.0		Some diglycerides but mainly triglycerides (C_4,- C_{18}, C_{18-1}, C_{18-2}, C_{20-2} and C_{20-3})
Oher lipids	0.05		Lecithin, cephalin, sphingomyelin
Proteins	3.38		**Caseins, 2.7% of which**
			α-casein, 1.62%
			ß-casein, 0.60%
			γ-casein, 0.1 1%
			k-casein, 0.36%
			Whey proteins, 0.60% of which:
			α-lactalbumin, 0.13%
			ß-lactoglobulin, 0.35
			serum albumin 0.04%
			immunoglobulin, 0.08%
			Traces of other nitrogenous substances
Lactose	5.0		Milk sugar
Salts and minerals	0.9		Calcium, magnesium, sodium potassium, phosphates, citrates, chlorides, sulphates, (iron, manganese, copper, cobalt, etc.).
Water	87		
		Minor constituents	
Pigments		Carotene, riboflavin, xanthophyll	
Enzymes		Lipases, proteases, reductases, phosphatases, lactoperoxidases, catalase, oxidases, etc.	
Vitamins		Fat soluble : D, E and K Water soluble: C and the B group	
Gases		Oxygen, nitrogen, carbon dioxide (as carbonic acid), ammonia, Sulphuretted hydrogen, etc	
Volatiles		Extraneous volatiles: petrol, paraffins etc.	
Cellular matter		Epithelial cells, leucocytes	
Micro-organisms yeasts,		Bacteria (normal udder flora) & microbial contaminants (i.e. bacteria, moulds etc.).	
Contaminants		Seeds, straw, leaves, disinfectants, manure, urea, soils and even fuel oils. (Note that the presence of the contaminants is a result of carelessness during milk production)	

Table 2.2: Composition of full-fat and skim milk.

Milk component	Full-fat milk		Skim milk	
	(a)	(b)	(a)	(b)
Water, %	87.99	87.98	90.80	89.33
Fat, %	3.34	3.43	0.18	2.01
Protein, %	3.29	3.25	3.41	3.26
Lactose, %	4.66	4.80	4.85	4.87
Ash, %	0.72	0.71	0.76	0.72

(a) Kosikowski and Mistry (1999b), (b) Smit *et al.* (1998a)

2.1.3 The role of milk components in cheesemaking

2.1.3.1 Fat

According to Bylund (1995), the fat in cheese primarily determines the texture, flavour (taste and aroma), mouthfeel and consistency. Depending on the initial amount and composition in the milk, the effect of fat on the cheese quality will differ. The flavour of the cheese will depend primarily on the initial fatty acid and protein profiles of the milk itself and the developed flavours from the different metabolites formed during cheese ripening (Scott, 1998; Fox, McSweeny, Cogan & Guinee, 2004a).

Fox and McSweeny (1998) reported that nearly 10 % of the fat is lost in the whey during cheesemaking. The distribution and incorporation of the milk fat globules in the cheese depends on the globule size, since the smaller fat globules are incorporated more easily into the cheese matrix than the larger fat globules. The fatty acids of the milk and their distribution is based on their solubility and physical nature there being either short-chained or long-chained fatty acids. Most of the short-chained fatty acids, which have a high threshold for flavour development in cheese, are lost in the whey. The long-chained fatty acids, with some proteins, participate in the formation of the background flavour (Fox and McSweeny, 1998).

Low-fat cheeses with high protein contents are often dry and firm with a hard crumbly body. This is due to the increased cross-linking of the protein molecules within the curd particles and the loss of the plasticising action of the fat. Furthermore, these cheeses do not posses the cheesy flavour of full-fat cheeses that have a smooth texture and a creamy mouthfeel (Paz *et al*. 1998). According to Scott (1998), even 1 % of fat in milk will impart the characteristic cheese flavour.

2.1.3.2 Proteins

According to Bylund (1995) and Scott (1998), milk proteins act as a source of nitrogen for the growth of the starter culture during the fermentation process. Milk proteins include caseins and whey proteins in different concentrations (Table 2.1). These individual protein components play major roles in cheesemaking, especially during cheese ripening. Cheese can be considered to be a protein network that is formed due to the precipitation of casein micelles. Most of the whey proteins are lost in the whey. According to Fox and McSweeny (1998), approximately 5 % of the total protein is lost in the whey. Upon cheese ripening, the caseins and the remaining whey proteins are degraded (proteolysis) to form amino acids, peptides, ammonia and other chemical components that have a role in the development of the cheese flavour.

Proteins also play a role in texture development of the cheese, resulting in cheeses with high protein contents (e.g. skim milk, fat-free and often low-fat cheeses) having a firmer and more crumbly texture as compared to full-fat cheeses (Paz *et al*. 1998).

2.1.3.3 Lactose

According to Galloway and Crawford (1995) and Kosikowski and Mistry (1999a) lactose is the main substrate of enzymes for fermentation. It is degraded in a series of chemical reactions to form lactic acid. The lactase enzymes

responsible for this degradation are present in the starter culture. Lactic acid plays a major role in cheesemaking (see subsection 2.2.1).

Lactose contributes to the total non-fat solids (NFS) of unripened cheeses. In ripened cheeses lactose is degraded by the *Lactococcus* spp. in the starter culture within a short period of time during the fermentation process (Scott, 1998). According to Fox and McSweeny (1998), lactose gets depleted within two days of cheesemaking but in soft unripened cheeses it can still be present at levels of 1-2 % after two days.

2.1.3.4 Ash

The ash in milk, consists of a variety of salts and minerals at concentrations of less than 1 %. Ash contributes to the total solids content of the cheese as well as its nutritional value. Milk salts are present in solution, colloidal form or as part of the casein component (Brule and Lenoir, 1986). Minerals, such as copper and iron, form part of enzyme molecules. The most important minerals in cheesemaking are calcium, chlorides, sodium and magnesium. Calcium and phosphate molecules play a major role in milk coagulation. Upon acidification, demineralisation of the casein micelles occurs (see subsection 2.6.2.1) whereby the insoluble colloidal complex of calcium hydroxy phosphate is removed from the casein micelles (Bylund, 1995).

According to Fox, *et al*. (2004a), citrate acts as a substrate to those mesophilic cultures which have the ability to degrade it. With citrate metabolism, characteristic flavours are formed due to the presence of an essential flavour compound, diacetyl, which gives a typical flavour in unripened cheeses.

2.1.3.5 Enzymes

A variety of enzymes indigenous to milk, as well as enzymes produced by the milk microflora are present (Hicks *et al*. 1982). The most prominent enzymes in milk are proteases and lipases and their presence in cold-stored milk is regarded

unfavourable. They reduce its shelf life by causing degradation of milk proteins and lipids prior to cheesemaking. Cheese made from such milk tends to have a lower yield due to the premature loss of fat and protein (Hicks *et al*. 1982). Proteolytic enzymes involved in cheese-ripening include those indigenous to the milk, those in the starter culture and the enzymes from added rennet (Mara and Kelly, 1998).

During heat treatment most of the enzymes are inactivated. However, according to Fox and McSweeny (1998), only 85 % of the lipases are inactivated. These enzymes are of importance where strong cheese flavours are preferred, especially in cheeses made from raw milk. McSweeny, Fox and Olson (1995) reported that, during the production of Quarg, unlike plasmin (an indigenous enzyme to milk), which is destroyed by heat, cathepsin-D (a proteinase also occurring in milk) had the ability to exert a chymosin-like action in the manufacture of non-renneted cheeses. At low pH values of 4.0 it influences proteolysis and may contribute to the ripening of Quarg with pH values of ~4.4 whereby, the enzyme, with chymosin-like character denature the caseins and thus the protein structure is degraded with further developments of flavours.

2.1.3.6 Water

Water plays an important role in the milk as well as in the cheese. The amount of water available in full-fat milk or skim milk is inversely proportional to the amount of the total solids. Cheese made from full-fat milk has a lower moisture content compared to skim milk cheeses (Scott, 1998).

Water in cheese plays a variety of roles (Scott, 1998):

- It affects the keeping quality of the cheese, when expressed as water activity (a_w). If the water activity is high in the product, the cheese tends to be highly susceptible to microbial spoilage since the high moisture content enhances microbial growth which may be accompanied by proteolysis and lipolysis.

- It affects the cheese yield whereby cheeses with high moisture content have higher yields.
- It affects the firmness or texture of the cheese, depending on the extent to which water in the form of whey was removed during manufacturing.

2.2 QUALITY ATTRIBUTES OF STARTER CULTURES USED IN CHEESEMAKING

2.2.1 Overview

Different kinds of starter cultures are used in the production of a variety of cheeses (Shaw, 1986; Farkye and Vedamuthu, 2002). In typical cheese fermentation processes, lactic acid bacteria (LAB) are mainly used. The major role of LAB is the degradation of lactose to galactose and glucose with the subsequent formation of lactic acid. According to Jay (2000), LAB include the genera *Lactococcus, Lactobacillus, Leuconostoc, Pediococcus* and *Streptococcus.* These microorganisms can either be homofermentative, strictly producing lactic acid as the major end-product of fermentation or heterofermentative, producing lactic acid and some other flavour components which are a result of a complex mixture of chemical compounds arising from enzymic interactions. Such chemical compounds include acids from lactic acid fermentation, acids from lypolysis and peptides from proteolysis.

Bylund (1995) gave another basis according to which LAB starter cultures can be categorized:

1. Their optimum temperatures: mesophilic cultures have optimum growth temperatures between 20 and 30 °C, whereas thermophilic cultures have optimum temperatures between 40 and 50 °C.
2. Their composition: whether it is a single, mixed or multiple strain culture.
3. According to aroma production with different culture groups/culture strains whereby one or two microorganisms will be the sole producers of the aroma: the O or N culture group produces no aroma, whereas the B, D, BD or LD culture groups have the ability to produce the required aroma in the cheese.

Aroma is mainly produced by *Lactococcus lactis* ssp. *lactis biovar diacetylactis* and *Leuconostoc* spp.

Starter culture enzymes contribute to the degradation of the milk components through chemical reactions such as glycolysis, lipolysis and proteolysis (Galloway and Crawford 1985; Choisy *et al*. 1986; Bylund, 1995; Fox and McSweeny, 1998; Scott, 1998). From these reactions minor and major chemical metabolites are formed and these contribute to the final cheese flavour.

The lactic acid produced, plays several major roles:

- The lowering of the pH of the medium (milk or cheese), and hence controlling enzymatic activity or chemical reactions.
- The ability to produce antimicrobial substances, hence, suppressing the growth of spoilage microbes and pathogens.
- The establishment of low Eh values, hence, promoting the production of reduced sulfur compounds (e.g. methanethiol, a typical flavour component). The low levels of O_2 which are maintained, play a role in the natural selection of microbes by inducing either aerobic or anaerobic conditions.
- Enhancing whey expulsion and, therefore, indirectly regulating the moisture content of the cheese.

2.2.2 Lactic acid bacteria involved in the production of cottage cheese

For the production of cottage cheese, a mesophilic type of culture is used (Fox and McSweeny, 1998; Kosikowski and Mistry, 1999a). It is an LD or BD type mixed culture which may contain mixtures of two or more of the following genera: *Lactococcus lactis* ssp. *cremoris, Lactococcus lactis* ssp. *lactis biovar diacetylactis, Lactococcus lactis* ssp. *lactis and Leuconostoc mesenteroides* ssp. *cremoris* (IDF, 1991). These cultures are heterofermentative and have the ability to utilise milk citrate to produce the characteristic flavour compounds such as diacetyl and acetate (Figure 2.1) by *L. lactis* ssp. *lactis biovar diacetylactis* and *Leuconostoc* spp. (Varnam and Sutherland, 1994; Fox *et al*. 2004a).

The incubation temperatures of the mesophilic starter cultures are between 21 and 30 °C depending on the setting methods applied. Setting methods are based on milk coagulation periods and the concentration of the culture. For the long-set method, a 16 h incubation period is required at temperatures between 21 and 22 °C with a starter concentration of 1 %. The short-set method, on the other hand, requires 5 h of incubation at 30 °C and a starter concentration of 5 % (Kosikowski and Mistry, 1999a).

Figure 2.1: Citrate metabolism. Adapted from: Fox *et al.* (2004a)

According to Fox and McSweeny (1998), mesophilic cultures often cause bitterness in the cheese. This is due to their high cell numbers in correlation with an increased activity of proteases. This effect leads to increased hydrolysis of the non-bitter peptides with high molecular weight to bitter peptides, often of lower molecular weight. The bitterness can be attributed to the presence of hydrophobic amino acid residues of these peptides.

Mesophilic cultures do not have high proteolytic activity when compared to other lactic acid bacteria. This is because higher proteolytic effects recorded for other

LAB are at pH values of 5.5 or higher while the optimum pH range for mesophilic cultures is between 4.6 and 4.8. Lactic starter cultures, compared to some yeasts and moulds, have a weak esterase (lipolytic) activity, and hence, they can only act effectively on partially hydrolysed fat (Choisy *et al*. 1986).

According to Lake Foods International (tel:++2711-409 5009), the supplier of freeze-dried vat set (DVS) commericial starter cultures, after 6 h of incubation the pH values of the medium, are in the range of 5.4 and 5.7 with a microbial concentration of 5 x 10^{10} cfu/g, of which *Leuconostoc* comprises 1 to 10 % and *Lactococcus* 3 to 30 %. The salt content at levels of 3.7 %, will give a 50 % inhibition rate of the starter culture, while a salt concentration of 6 % results in a 100 % inhibition.

2.3 MILK TREATMENT PRIOR TO CHEESEMAKING

A number of processes may be applied to milk prior to cheesemaking. These include heat treatment (thermisation at ± 50 °C, pasteurisation, Ultra High Heat Treatment), bactofugation, homogenisation, milk standardisation, milk separation and ultrafiltration. For milk intended for the production of soft unripened cheeses, pasteurisation and milk separation are the two most important pre-processing parameters (Galloway, 1995).

2.3.1 Basic treatments applied to cheesemilk for cottage cheese production and their effect on the quality of milk

2.3.1.1 Pasteurisation

Pasteurisation is a heat treatment capable of destroying all asporogenic pathogens, the spoilage bacteria and some of their active enzymes. Upon heat treatment, depending on the heat intensity and the time of exposure, milk components may be affected. Milk is often batch-pasteurised at 80 °C for 30 minutes on small-scale production, or plate-pasteurised at 90 °C for 5 seconds, on a larger scale (Galloway, 1995; Scott, 1998).

This processing parameter often affects milk proteins, lactose and some enzymes, depending on the heat intensity.

- Proteins. Heat treatment at temperatures higher than 72 °C denature whey proteins. The α-lactalbumin and ß-lactoglobulin precipitate on the caseins, forming a protein network or complex. This condition is not desirable in renneted type of cheese since it increases the coagulation time. In soft cheeses, where rennet is not used, this has a positive effect where the interaction of this complex and the caseins contribute to the overall quality of the cheese by increasing the viscosity, combating syneresis and increasing the cheese yield (Kelly and O' Donnell, 1998).

- Lactose. Lactose, when heated to very high temperatures, tends to react with some of the amino acids resulting in the Maillard reaction. This reaction has a negative effect on the milk colour, which turns brownish. In cheese, the colour as well as the developed caramel taste, will affect the primary characteristic cheese flavour and such milks are not suitable for the production of soft cheeses (Bylund, 1995). Webb, Johnson and Alford (1986) and Jelen and Renz-Shauen (1989) assessed the relationship between the denatured whey proteins, moisture and lactose content. The moisture trapped by the denatured whey proteins increased the solubility of the lactose that remained in the curd. From a nutritional point of view, high lactose contents in soft cheeses may render them unsuitable for persons suffering from lactose intolerance.

- Enzymes. All, or most of the enzymes, indigenous to milk like plasmin, will be inactivated at pasteurisation temperatures. However, some of the enzymes are heat resistant and their presence will tend to have a negative effect on the milk quality. For example, the occurrence of plasmin will degrade the milk proteins and this will lead to low cheese yields as well as the development of bitter flavours, resulting from the formed peptides (Scott, 1998).

2.3.1.2 Milk separation

This process is applied to obtain skim-milk with a fat content of 0 to 0.2 %. Prior to separation, milk is heated to temperatures between 40 and 50 °C so as to melt the fat globules and increase the efficiency of separation (Varnam and Sutherland, 1994).

According to Winwood (1983), the use of fresh skim-milk is preferred to that of reconstituted milk. The latter tends to produce cheese with a very high moisture content due to the presence of high levels of denatured whey proteins (produced during spray drying) that lead to rapid cheese spoilage. On the contrary, high levels of whey proteins participate in increasing the cheese yield.

According to Bylund (1995), vital lipoproteins such as cryo-globulins occur in cold- stored milk. These lipoproteins determine the efficiency of milk separation, depending on temperatures applied. If lower temperatures (less than 40 °C) of separation are applied, the lipoproteins are often retained in the milk serum and their presence contributes to milk rancidity. Inversely, at high temperatures, they are denatured and, as a result, affect milk coagulation, especially in renneted cheese types. The denatured whey proteins precipitate on the caseins rendering milk not suitable for use in hard-cheese manufacturing. It is recommended that separation temperatures between 40 and 50 °C be applied in order to destroy the lipoproteins (Fox and McSweeny, 1998).

2.3.1.3 Homogenisation

At lower temperatures the milk fat globules cluster and cause the creaming effect by concentrating on the milk surface. In full-fat cottage cheese these globules tend to affect the rate of whey drainage and the cheese might retain more moisture (Webb, Johnson & Alford, 1986; Bylund, 1995). This effect can be eliminated by homogenising the milk prior to cheesemaking. However, according to Scott (1998), homogenisation may increase the risk of fat-hydrolysis that may result in rancidity, thereby rendering the milk unsuitable for cheesemaking.

2.4 QUALITY ATTRIBUTES OF COTTAGE CHEESE

2.4.1 Background

Cottage cheeses are also referred to as soft unripened cheeses, fresh cheeses or fresh lactic acid curds. They are characterised by a high moisture content, low fat content, mild acidic flavour, short shelf life, with the optional use of rennet and no pressing of the curd. A ripening period is not essential since they are usually consumed fresh (Shaw 1986; Galloway, 1995; Scott, 1998; Kosikowski & Mistry 1999a).

According to Winwood (1983), Shaw (1986) and Galloway (1995), soft cheeses can be classified according to:

- their moisture content;
- their fat content;
- the type of milk used speies specific either cow, goat etc., whether full-fat or skim milk; and
- the ripening period.

They can also be classified into categories based on their fat contents, e.g:

- full-fat cheese:20 to 40 % fat and not more than 60 % water;
- medium-fat cheese:10 to 20 % fat and not more than 70 % water;
- low-fat cheese: 2 to 10 % fat and not more than 80 % water; and
- skim-milk cheese: 0 to 2 % fat and not more that 80 % water.

Depending on the production method used, where the cheese curds may be cooked, creamed or further fermented, the composition, physical and microbial qualities of these cheeses will differ and therefore several varieties of soft unripened cheese exist. Some of the examples include: Bakers (U.S.A.), Cream cheese (U.K.), Quarg (Germany), Ymer (Denmark) and Neufchâtel or Fromage Frais (France) (Kosikowski and Mistry, 1999a). A functional classification of soft cheeses is shown in Figure 2.2. (Shaw,1986).

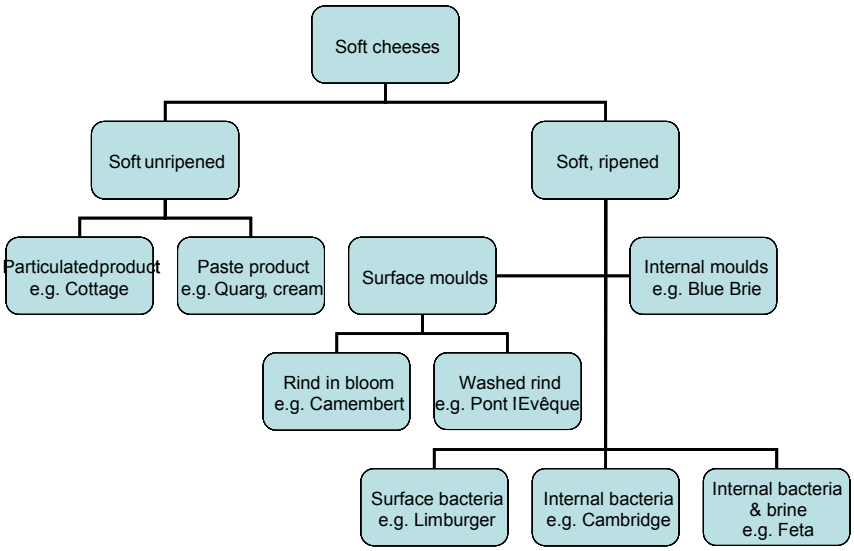


Figure 2.2: Classification of soft cheeses. Adapted from Shaw (1986).

2.4.2 Composition and physico-chemical properties of cottage cheese

The composition of soft cheeses differs mainly because of the fat content and other components of the milk (Table 2.3). As mentioned in subsection 2.1.3.1, the texture of the cheeses will differ according to their fat content. Skim milk cheeses have higher protein contents than the full-fat cheeses. On the contrary, full-fat cheeses have high levels of total solids (Paz *et al*. 1998). According to Mara and Kelly (1998), higher protein contents of approximately 23.2 % might occur due to the increased levels of denatured whey proteins, if high heat-treated milk is used. The pH values of these cheeses are normally between 4.3 and 5.0, the water activity (a_w) between 0.96 and 0.99 and the titratable acidity approximately 0.55 to 0.6 %, expressed as lactic acid (Shaw, 1986). According to Scott (1998) and Bylund (1995), the pH of most cheeses increases with time as a result, of the rate of microbial activity during the first few days of manufacturing.

Table 2.3: Literature values for the composition of full-fat and skim milk cottage cheese

Cheese type	Moisture %	Fat %	Protein %	Solids %	Lactose %	Ash %	Salt %	Reference
FFCC	75.16	11.02	9.41	24.84	3.56	0.85	0.4-0.8	Smit *et al*. (1998b)
	71.8	16.3	na	na	na	na	na	Fox *et al*. (2004b)
	72.0	8.0	15.0	na	3.0	0.8	0.8	Kosikowski and Mistry (1999a)
SMCC	80.5	0.2-0.4	na	19-21	na	na	0.06-0.12	Shaw (1986)
	83.65	0.14	10.51	16.44	4.85	0.95	na	Scott (1998)
	82.5	trace s	1205	17.5	3.5	0.7	na	Smit *et al*. (1998b)
	Na	0.2	11.8	na	na	na	na	Winwood (1983)
	79.0	0.4	16.9	na	na	na	na	Galloway (1995)
	78.0	0.5	13.0	22.0	2.0	na	na	Koth and Richter (1989)

(na) Data not available; (FFCC) full-fat cottage cheese; (SMCC) skim milk cottage cheese

This is due to a shift in the buffering system. Upon the degradation of either proteins or lipids, minor metabolites are formed. These metabolites have basic or alkaline properties and, as a result, their presence increases the pH.

2.4.3 Organoleptic properties

The organoleptic properties which typify soft unripened cheeses include the milky, white colour, soft body, smooth texture, a good spreadability, no signs of syneresis on the cheese surface, no dryness or grittiness and a mild to acidic flavour (Winwood, 1983; Koth and Richter, 1989). All these qualities are influenced by the chemical composition of the cheese.

2.4.4 Cheese flavour

According to Fox and McSweeny (1998), cheese flavour is regarded as a component of taste and aroma. Taste refers to the water soluble fraction which includes peptides, amino acids, organic acids, salts and amines, whereas aroma is the volatile fraction including free fatty acids and chemical components. Skim milk cheeses often have a bland flavour and most are used as food bases. The flavour of soft cheeses can either be natural or acquired. The natural or primary cheese flavour is regarded as that which originates from the enzymatic activity of the starter microbes, whereas the acquired or secondary flavour is due to the addition of other ingredients in the finished products (Scott, 1998).

The natural flavour, which is typical of fresh cheeses, is due to the presence of chemical components, e.g. diacetyl and acetate, which originate from the degradation of the milk citrate by the mesophilic starter culture. According to Galloway (1995), Scott (1998) and Kosikowski and Mistry (1999a), the acquired flavour originates from added condiments such as onions, spices and a variety of vegetables for savoury products and fruit pulps for dairy desserts. Early (1992) considers it essential for the savoury products to have a low fat content of 0 to 0.3 % and dairy desserts to have higher fat contents of 3 to 6 %, so as to have a creamy mouthfeel and consistency.

2.4.5 Cheese microbiology and shelf life

Cottage cheese is susceptible to microbial growth due to its high moisture content and high pH values and these factors determine its shelf life. The microbial growth and activity in cheese is influenced by the storage period, storage temperature, salt content, pH, packaging material and the nutrient content (Early, 1992; Varnam and Sutherland, 1994; Bylund, 1995; Kelly and O' Donnell, 1998). Hence, cottage cheese has a limited shelf life of three to four weeks.

Bishop and White (1985) reported that the presence of spoilage organisms and their metabolites may be used to estimate the shelf life of cottage cheese. Spoilage microbes associated with cottage cheese include coliforms and enzymes of the psychrotrophic *Pseudomonas* spp. Coliforms in general, are often associated with post-pasteurisation contamination during cheese production and may be regarded as indicators of unsanitary conditions. It is recommended that their presence in cheese be detected within 48 h of manufacture (Houghtby, Maturin and Koeng, 1992).

Except for the occurrence of *Pseudomonas* and coliforms and their enzymes, spoilage may also be a result of starter culture failure, the presence of the indigenous microflora of the milk and their enzymes. These microbes are able to grow at low pH values of 4.0 (Jay, 2000). Only lactic acid bacteria, yeasts and moulds are able to grow at pH values below 5.0 (Choisy *et al*. 1986). Yeasts and moulds associated with surface growth on most cottage cheeses are mainly *Penicillium* spp. *Geotrichum* spp. *Mucor* spp. and *Alternaria* spp. (Zakrzewski, Stepaniak, Abrahamsen and Sorhaug, 1991). According to Bishop and White (1985), defects as a result of the lapsed time associated with cottage cheese types are: slime formation, surface discolouration, off-flavours and off-odours.

2.4.6 Cheese yield

The yield of soft cheeses will differ depending on the type of milk used, whether it is full-fat or skim milk (Scott, 1998). Cheeses made from skim milk have yields of 17.5 % and those from full-fat milk approximately 25 %.

The lower yield in the skim milk cheeses is due to the low levels of total solids (Kosikowski and Mistry, 1999a). Both Early (1992) and Banks *et al*. (1994), found that the cheese yield obtained when thermised skim milk is used, is higher due to the accumulation of denatured whey proteins. If cheese is to be manufactured from milk with a high psychrotrophic count, the cheese yield will be

lower due to the degradation of the milk components, including lipids and proteins, which will then not be part of the cheese matrix (Hicks *et al*. 1982).

The use of added ingredients will increase the cheese yield, depending on the amount added (Scott, 1998). Shah, Jelen and Ujvardsy (1990) showed that the use of rennet in soft cheese increased the cheese yield. Although rennet enhanced whey separation from the curds, it prevented the excessive loss of the casein proteins. Kelly & O' Donnell (1998) reported that the same effect applies when high-heat treated milk is used since the denatured whey proteins, which precipitate on the casein, will retain moisture and thus increase the cheese yield. The lactoglobulins are responsible for the gross yield by retaining water and the lactalbumins determine the rheology of the cheese.

2.5 PRINCIPLES OF MANUFACTURING COTTAGE CHEESE

2.5.1 Background

According to Galloway (1995), Scott (1998) and Kosikowski and Mistry (1999a), the basic steps involved in the production of fresh cheeses on a small scale include:

1. milk setting (coagulation);
2. hooping of coagulum and whey drainage;
3. salting; and
4. addition of condiments.

2.5.2 Basic cheesemaking operations

2.5.2.1 Milk setting (coagulation)

To coagulate the milk, starter cultures are used. The addition of rennet in manufacturing unripened type of cheeses is not essential (Webb *et al*. 1986; Weber, 1986; Bylund, 1995). Milk is acid-coagulated by mesophilic starter bacteria (subsection 2.2.2) and either long-set or short-set methods are applied to set the milk. For the long-set method, milk is incubated for 16 h at

temperatures between 21 and 22 °C and for the short-set method, 5 h of incubation are required at 30 °C.

Milk coagulation is based on the principle of casein precipitation by lactic acid at its isoelectric point of pH 4.6. Upon acidification, demineralisation of the casein micelles occurs whereby the insoluble colloidal complex of calcium-phosphate is removed from the casein micelles. The casein micelles disaggregate, their hydration level is reduced and they thus become highly insoluble. A gel (the insoluble mass) is formed which will later be firm in consistency and form the coagulum or cheese curd (Galloway and Crawford, 1985; Brule and Lenoir, 1986; Bylund, 1995).

According to Brule and Lenoir (1986), the coagulum is affected by a variety of factors which include:

- the protein content;
- the temperature and time of coagulation;
- the rate of acidification; and
- the pH of the milk.

According to Sohal, Roehl and Jelen (1988) and Mara and Kelly (1998), the use of rennet in fresh cheeses resulted in excessive proteolysis in the cheese, during storage. This effect led to premature cheese spoilage and significant flavour defects within three weeks, as compared to the expected shelf life of four weeks. However, apart from these detrimental effects of rennet, it plays a role in increasing the cheese yield, producing firmer textures and acting as a ripening agent.

Acid curds tend to have a weak coagulum as compared to those of the renneted cheeses due to the existing smaller, dispersed and demineralised casein particles. The curds have the ability to retain more moisture due to lack of contraction forces amongst the molecules. The available casein forms a plastic

mass which encloses the whey. Such curd particles are not smooth and have a brittle texture (Weber, 1986).

2.5.2.2 Curd hooping and whey drainage

After the coagulum has formed, it is slightly stirred and hooped into linen cloth bags. This principle is traditional and is based on the “Berge Process” (Figure 2.3).

Figure 2.3: The Berge Process. Adapted from: Kosikowski & Mistry (1999a).

Whey drainage is achieved by gravity and this method is applied only on small scale cheese manufacturing (Kosikowski and Mistry, 1999a). According to Galloway (1995), whey drainage for skim milk cheeses occurs within 12 h as compared to the 18-20 h of full-fat cheeses. The longer periods of drainage in the latter may be due to the blockage of the cloth pores by the fat.

2.5.2.3 Salting

Salt is applied to the cheese curds after they have been removed from the bags and less than 1 % of salt is added (Kosikowski and Mistry, 1999a). Salting of cheese, as was studied on Feta cheese, involves an exchange of calcium ions, which are loosely bound to the caseins, with sodium ions from the added sodium

chloride (Bylund, 1995). The salt content of soft cheeses is often in the range of 0.4 to 0.8 % (Scott, 1998). According to Bylund (1995), different salt contents are obtained for different cheese varieties (Table 2.4).

Table 2.4: Salt content of cheese varieties. Adapted from Bylund (1995)

Cheese Type	% Salt (NaCl)
Cottage cheese	0.25-1.0
Emmental	0.4-1.2
Gouda	1.1-2.2
Cheddar	1.75-1.95
Limburger	2.5-3.5
Feta	3.5-7.0
Gorgonzola	3.5-5.5

The amount of salt added to cheese plays a major role in the quality of the cheese (Hardy, 1986; Scott, 1998; Bylund, 1995). For example:

- It affects the growth of microorganisms and their enzymatic activity directly by inhibition, or indirectly, by lowering the water activity;
- It promotes the release of enzymes by the starter bacteria and as a result affects the ripening process and furthermore;
- It also adjusts the moisture content of cheese by enhancing further whey drainage.

According to Fox, McSweeny, Cogan and Guinee (2004b), salt absorption and distribution in the cheese may be affected by the pH, the time of salting and the fat content of the cheese. This theory is based on results obtained from studies conducted on Feta cheese. Bylund (1995) reported that salt penetration occurs over longer periods in high-fat cheeses as compared to low-fat cheeses, and at lower pH values, more salt is absorbed.

2.5.2.4 Addition of condiments

A variety of condiments can be added to the cheese bases whereby the product may either be of a savoury type or a dairy dessert (Shaw, 1986). As reported by Mann (1990), the most popular fruit used for the production of sweetened dairy desserts is strawberries. Fruit pulp is added at concentrations of 10 to 20 % (Kosikowski and Mistry, 1999a) or 19 to 22 %, as in most German products (Koth and Richter, 1989).

According to Tamime and Robinson (1999), the use of fresh fruit in dairy desserts is limited due to their seasonal availability. Instead, fruit preserves, canned and frozen fruits are preferred due to their standard composition, specifications as well as availability and consumer demand.

2.6 Trends in extending the shelf life and increasing the yield of cottage cheese

2.6.1 Methods of extending the shelf life of cottage cheese

Traditionally the shelf life of most cheeses is extended by the use of a variety of chemical substances as preservatives. These include salt (NaCl), potassium sorbate or Sorbistat-K® and antimicrobial substances such as Nisin and Natamycin (pimaricin). With recent technologies, other methods have been developed to extend the shelf life of cottage cheese to 10 to 12 weeks as compared to the typical 1 to 2 week shelf life. Some of these methods are applied in conjunction with the use of preservatives (Shaw, 1986; Varnam and Sutherland, 1994).

2.6.1.1 Thermisation

Cheese is subjected to a heat treatment of 60 to 80 °C for 2 to 3 minutes in its packaged form. Heat penetration is targeted at the cheese surface (the headspace) where most of the spoilage aerobic microorganisms occur. The heat treatment inactivates almost all the existing microorganisms including those of the starter culture (Shaw, 1986; Zakrzewski *et al*. 1991; Rosenthal, Rosen and Bernstein, 1996). In studies conducted by Zakrzewski *et al*. (1991), thermisation

inhibited the growth of psychrotrophs, in particular *Pseudomonas* spp. However, the process showed some negative effects on the cheese quality as the heat applied resulted in further casein contraction and hence whey separation. The texture and the appearance of the cheese were thus affected.

Rosenthal *et al.* (1996) observed the same effect of microbial inactivation which resulted in an overall reduction of acidification of the product by the spoilage bacteria. By applying heat treatments of 55 °C on the cheese surface, the growth of yeasts and moulds was inhibited. This inhibition resulted in low levels of the free fatty acids produced due to the inactivation of lipases produced by yeasts and moulds. The LAB counts declined from 10^8 to 10^6 cfu /g of cheese. According to Early (1992), if the cheese curds are intended for thermisation (second heat treatment), it is important to use both mesophilic and thermophilic LAB cultures. The latter are able to survive the high heat treatments.

2.6.1.2 Ultra-high temperature treatment

Ultra high temperature principles are applied to produce long life products. Most or all of the spoilage microorganisms are destroyed at temperatures of 120 °C or above. This process, however, has negative effects on the protein quality since proteins are destabilised and this causes further whey separation (Jensen and Stapelfeldt, 1991). According to Paz *et al*. (1998), the use of hydrocolloids, which act as stabilisers in low-fat cheeses, is recommended. The added hydrocolloids control the cheese rheology and often do not affect the cheese flavour. The most popularly used hydrocolloids are, for example, guar gum and carrageenan.

2.6.1.3 Direct acidification

With the direct acidification method, acidification is achieved by the addition of specific organic acids such as citric acid, acetic acid, lactic acid and the synthetic D-glucono-delta-lactone. In these cases, milk is acidified to a pH of less than 5.0 when cold (at temperatures between 3 and 5 °C). Milk coagulation is based on

the principle of destabilising the minerals. After acidification, the milk is heated to 30 to 32 °C. The presence of an acidogen or added organic acids upon hydrolysis produces gluconic acid at a controlled rate till a pH value of 4.7 is reached. Such cheeses, however, tend to have a bland flavour due to the lack of enzymatic reactions (Shaw, 1986).

2.6.1.4 Use of special cultures

A variety of microbes can be used to control acid production during cheesemaking. Such cultures have a limited acidification rate below pH values of 4.8 to 5.0. When used, the acidity of the cheese can be controlled, hence indirectly controlling its shelf life. These special cultures are mixed cultures which include *Streptococcus* sp, *Lactococcus lactis* ssp. l*actis*, *Lactococcus lactis* ssp. *lactis biovar diacetylactis*, *Leuconostoc mesenteroides* ssp. *cremoris*, *Lactobacillus* sp. and *Bifidobacterium bifidum* sp. The latter has an essential stabilisation effect in avoiding over acidification of the product (Shaw, 1986).

2.6.1.5 Addition of fruit pulps

According to Campbell (1989), the addition of fruit pulps to soft unripened cheese resulted in enhancing its keeping quality as the acidity of the added fruit pulps contributed to that of the cheese. The sugar concentration played a role in lowering the a_w of the cheese, thus minimising the microbial activity and thus enhancing the shelf life. The cheese samples with added fruit preserves were still acceptable after 28 days whereas those without the added preserves were only acceptable up to 14 days. The results also showed that the added fruit preserves had the ability to mask the premature development of off-flavours in the cheese.

2.6.2 Methods of increasing the cheese yield

According to Shaw (1986), there is preference, by the large dairy companies to produce soft unripened cheeses on a large scale and not using the traditional methods. The increase in cheese yield when advanced methods are applied is

important because, with whey drainage, most of the valuable milk components (lactose, inorganic salts and proteins) are lost in the whey (Weber, 1986). Increase in cheese yield involves the standardisation of protein, especially whey proteins, which could be incorporated directly as whey protein concentrate (WPC) or indirectly, with high heat treatment of the cheesemilk or with ultrafiltration (Jensen and Stapelfeldt, 1991; Lawrence, 1991).

2.6.2.1 High heat treatments

This process, also termed thermo-processing, whereby minimal heat is applied to soft cheeses to increase their cheese yield (Early, 1992). Higher pasteurisation temperatures of 85 to 95 °C or above are applied to the milk with 30 minutes holding times. Milk is acidified and the resultant cheese is heat treated further at 56 to 60 °C (see subsection 2.6.2.2; Figure 2.4). At temperatures above 60 °C whey proteins are denatured, entrapped in the cheese curd and this increases the cheese yield (Bylund, 1995) and at 80 °C, 5 % of the whey proteins get denatured (Banks *et al*. 1994). With thermo-processing there is a 50 % protein recovery which often results in a 10 % increase in the cheese yield. Thermo-processing also has negative effects because the denatured proteins are liable to undergo proteolysis that might result in the development of unfavourable flavours in the cheese. However, compared to ultrafiltration, the application of high heat treatment has an advantage since it may improve the bacteriological status of the milk by reducing the number of spores in milk (Jensen and Stapelfeldt, 1991).

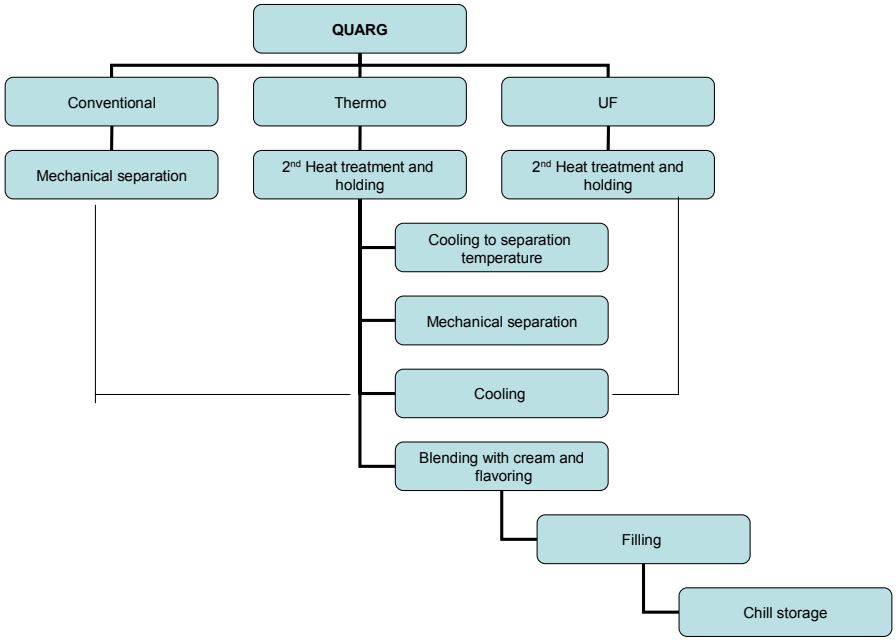


Figure 2.4: Basic processing steps in the manufacture of Quarg. Adapted from Early (1992)

2.6.2.2 Ultrafiltration

Ultrafiltration is often used for the concentration of acid-coagulated milk proteins. The stabilisation of the milk pH is essential, hence milk is ultrafiltered at pH 6.7. After ultrafiltration, it is fermented to be in the range of pH 4.4 to 4.6 (Pedersen & Ottosen, 1991). Often, a slight heat treatment is applied to the fermented curds, which are then passed through a porous membrane for the removal of the whey (Figure 2.4) and further retention of denatured proteins (Early, 1992). With ultrafiltration, the cheese yield will be 18 % higher with an increased protein content in the range of 12 to 13 % (Early, 1992; Scott, 1998).

2.6.2.3 Use of ultrafiltrated milk

The application of ultrafiltration in cheesemaking allows the retention of whey proteins in the cheese and thus an increase in the cheese yield (Renner and Abd El-Salam, 1991). With ultrafiltration, skim milk is concentrated to a total solids

content of 17-20 % (Table 2.5) after which it is fermented by the addition of a starter culture and with this technique, the cheese yield could increase up to 40 %. However, the high levels of the accumulated whey proteins might affect the organoleptic properties of the cheese (Scott, 1998). According to Jensen and Stapelfeldt (1991), in cheesemaking, the high calcium content of UF skim milk may cause a crumbly texture.

Table 2.5: Composition of Quarg made from ultrafiltrated concentrate and from skim milk. Adapted from Winwood (1983)

Milk component (%)	From UF- concentrate	From skim milk
Total solids	17.2	17.4
Fat	Traces	Traces
Protein	12.2	12.1
Lactose	5.1	2.8
Ash	1.59	0.94
Calcium	0.41	0.13

2.6.2.4 Incorporation of whey proteins

Whey protein concentrate can be added to the cheesemilk in a powdered form prior to processing. This addition will result in an increased cheese yield of up to 60 %. However, these proteins may affect the organoleptic properties of the cheese (Banks *et al*. 1994).

CHAPTER 3

MATERIALS AND METHODS

3.1 MATERIALS

3.1.1 Fresh milk

Fresh milk was obtained from the Milk Production Unit of the ARC-Animal Production Institute, Irene, on each day of cheese manufacturing. Three replications were conducted over a period of four months.

3.1.2 Starter culture

A freeze-dried direct vat set (DVS) commercial starter culture (CHN-22: Chr. Hansen Laboratories, Denmark) was used. It is a mixed, LD-type mesophilic-aromatic culture consisting of LAB, including *Lactococcus lactis* ssp. *lactis*, *Lactococcus lactis* ssp. *cremoris*, *Leuconostoc mesenteroides* ssp. *cremoris* and *Lactococcus lactis* ssp. *lactis (*biovar *diacetylactis)*. The commercial cultures were supplied by Lake Foods International, Johannesburg (++27 11 409 5009).

3.1.3 Fruit pulp

Strawberry fruit pulp of Agrana Fruit South Africa (Cape Town) was used and obtained from Fruimark Company (Midrand - S.A. Tel: ++27 11 614 1816). Apart from the requirements of a fruit pulp (Table 3.1), it should be pasteurized and aseptically packaged. The typical composition is shown in Table 3.1.

3.2 METHODS

3.2.1 Cream separation and full-fat and skim milk pasteurisation

For each of the three replications, cream was separated from 20 *L* of fresh full-fat milk using a small centrifugal separator with a capacity of 10 *L* (Elecrem Milk Separator, Boulogne, Italy). Prior to cream separation, full-fat milk intended to produce skim milk was subjected to a heat treatment of 40 to 50 °C for 15 minutes to destabilise the fat molecules, to facilitate the separation. Skim milk was collected and used in the trial. Both the full-fat milk and skim milk were batch pasteurised at 85 °C for 30 minutes and then subjected to various chemical

and physico-chemical analyses (Table 3.2). A 25 *L* capacity batch pasteuriser was used.

Table 3.1: Standard composition, chemical and microbiological status of the strawberry pulp. Adapted from Agrana Fruit-South Africa.

Additives	
Sugar	Sucrose
Stabiliser (E1422)	Modified waxy maize starch (E1422)
Flavourant	Nature identical
Colourant	Ponceau 4R
Preservatives	Potassium sorbate & Pimaricin
Analyses	
% Brix	4.6 - 4.8
pH	3.4 – 3.6
Microbial status	
Total plate count	< 100 cfu/g
Yeasts & Moulds	< 100 cfu/g
Staphylococcus aureus	0 cfu/g
Fruit concentration	
Strawberry Fruit (Classic)	45 %

3.2.2 Manufacture of cottage cheese desserts

Full-fat and skim milk cottage cheese desserts were manufactured as outlined in Figures 3.1 and 3.2, respectively. The manufacturing process is a modification of the methods described by Winwood (1983); Shaw (1986); Galloway (1995) and Scott (1998). The addition of, 0, 10, 20 and 30 % mass per volume (m/v) of the strawberry fruit pulp was used in the manufacturing process of the cottage

cheese desserts and afterwards subjected to various analyses as indicated in Table 3.2.

Table 3.2: Sampling and analyses protocol of milk, coagulum and curd during cottage cheese manufacture, as well as of cottage cheese dessert during storage at 4 °C

Analysis	Cottage cheese dessert manufacturing				FFCCD and SMCCD			
	Milk	Day 1 Milk	Day 2 Coagulum	Day 3 Curd	Day 1	Day 7	Day 14	Day 21
	Changes in the TA, pH and TCC							
TA		x	x	x	x	x	x	x
pH		x	x	x	x	x	x	x
TCC		x			x	x	x	x
	Chemical analysis and calculated values							
% Fat, Protein and Lactose		x						
% Fat					x			
* % FIDM					x			
% Protein					x			
% Lactose					x			
% Total solids	x				x			
* % Moisture					x			
* % MIFF's					x			
% Ash	x				x			
% Salt					x			
* % SIW					x			
* % TC					x			
* kJ					x			
* % Cheese Yield					x			

(FFM) Full-fat milk; (SM) Skim-milk; (FFCCD) Full-fat cottage cheese dessert; (SMCCD) Skim milk cottage cheese dessert; (TA) titratable acidity; (TCC) Total colony count; (FIDM) Fat-in-dry-matter; (MIFF's) Moisture in fat-free substances; (SIW) Salt-in-water; (kJ) Energy value; (TC) Total carbohydrates

* Calculated values

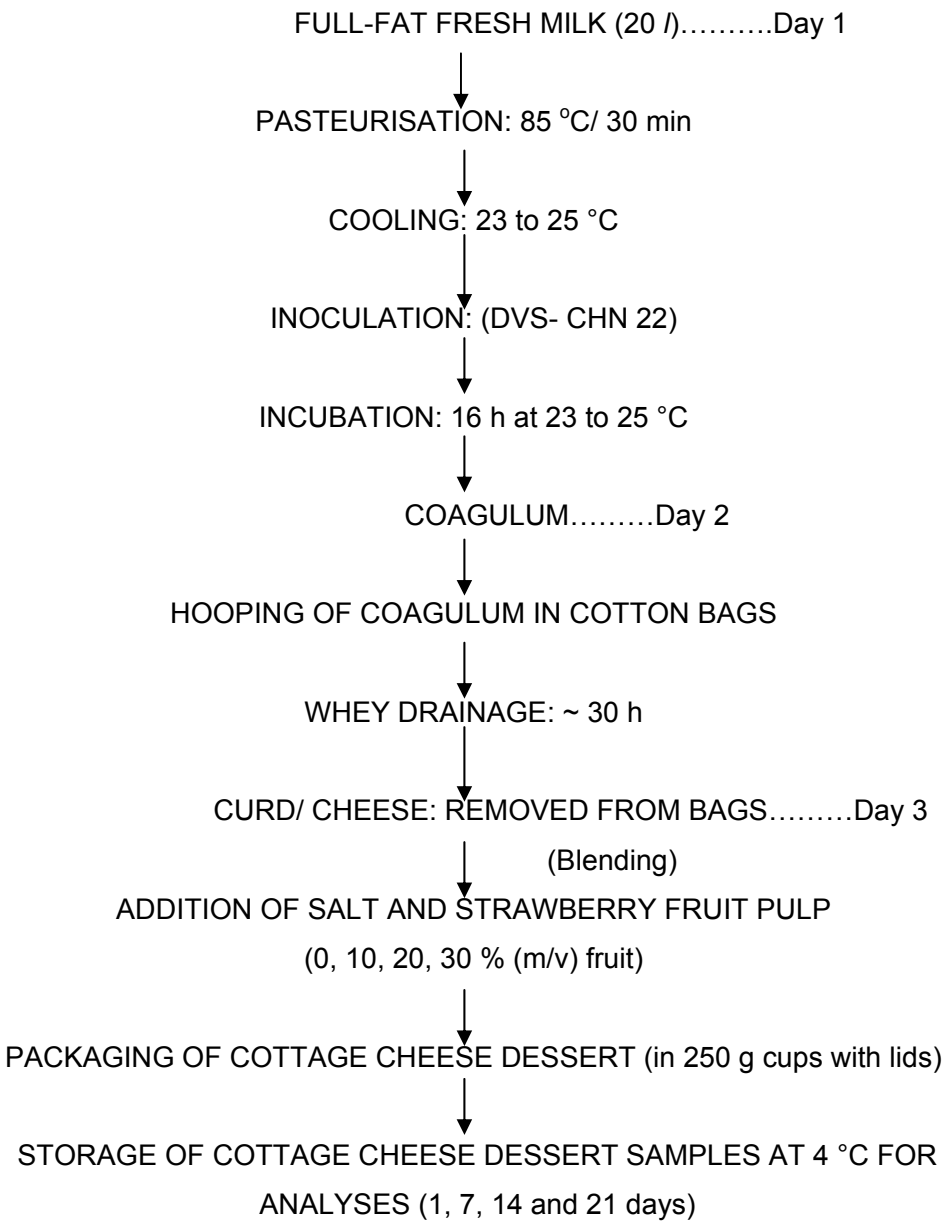


Figure 3.1: Process outline for the manufacture of full-fat cottage cheese dessert

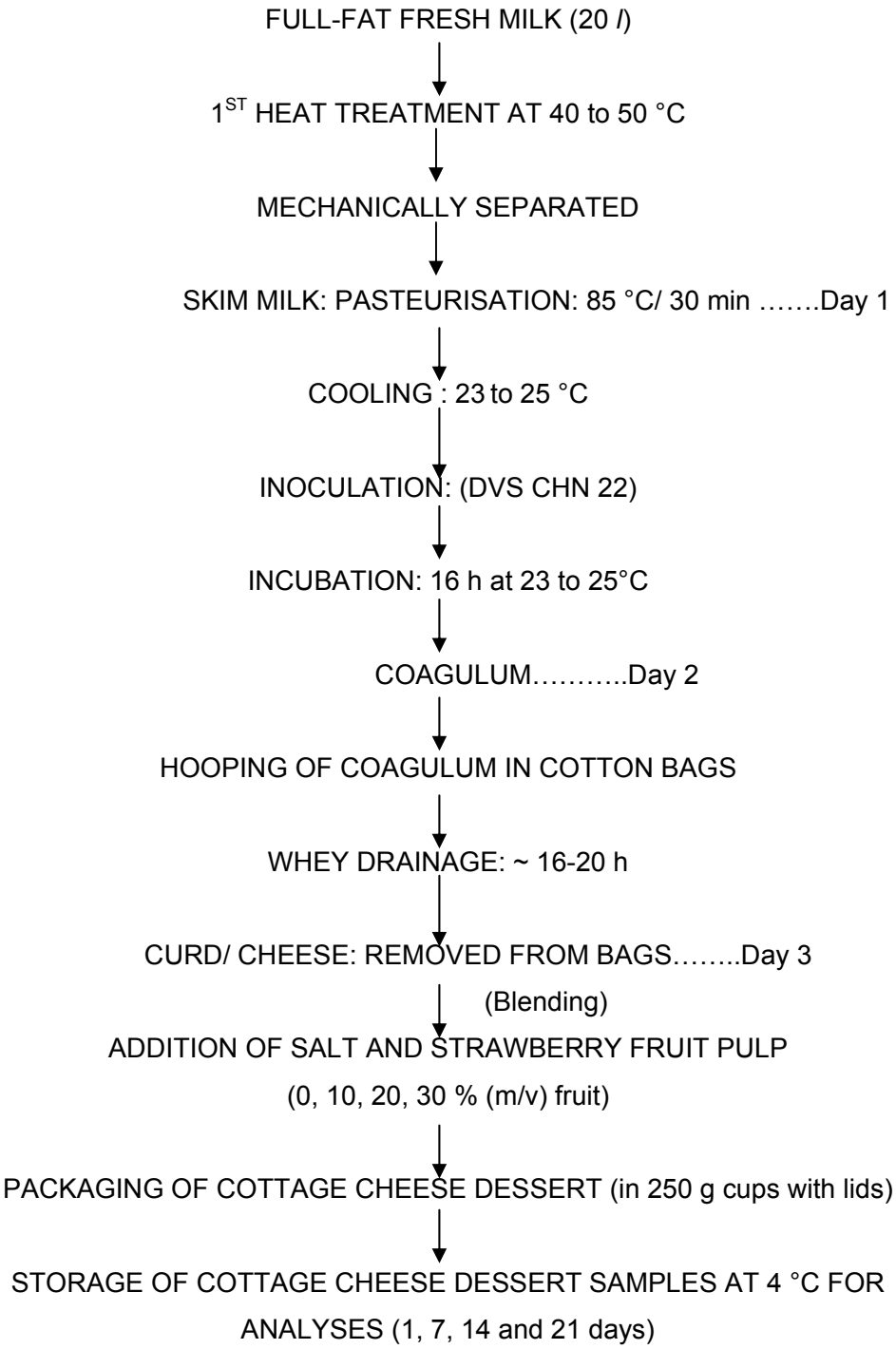


Figure 3.2: Process outline for the manufacture of skim milk cottage cheese dessert

3.2.3 Shelf life study

Samples were packaged in 250 g plastic cups with fitted lids and stored at refrigeration temperatures at 4 °C and until further analysis (Table 3.2).

3.2.4 Sampling and analyses protocol

Sampling of milk and cottage cheese desserts was done according to standard methods of sampling for milk and milk products (IDF, 1985). Separate milk samples for chemical and microbiological analyses were taken after pasteurisation and refrigeration (4 ºC) and analysed within three hours, on each day of production for the three trials. On day 1 (cottage cheese blending), the blended desserts were packaged and refrigerated (4 ºC) and samples for microbial tests were taken aseptically prior to those for chemical analysis. Microbial analyses were done within 24 hours and the rest of the analyses followed on days 7, 14 and 21. On the days of analysis, the dessert samples from each batch (FFCCD and SMCCD) were chosen randomly and analysed as indicated in Table 3.2.

3.3 ANALYSES

Analyses were done in duplicate and the experiment was repeated three times over a period of four months. During cheese manufacture, the titratable acidity (TA), pH, total colony count (TCC), fat, protein, lactose, total solids and ash content were determined on the full-fat milk (FFM) and skim milk (SM). The pH and TA were also determined on the coagulum (day 2) and the cheese curd (day 3). For the cottage cheese dessert, the TA, pH and TCC tests were carried out on a weekly basis for three weeks, on day 1 (after cheese blending), day 7, day 14 and day 21 whereas, the protein salt, moisture, total solids, fat, ash and lactose content were determined on day 1 (blended cheese) only. On the same day, calculated values for the % cheese yield, % total carbohydrates (TC), % salt-in-water (SIW), % moisture in fat-free substances (MIFF's), % fat-in-dry matter (FIDM) and the energy value (kJ) of the cottage cheese desserts were determined (Table 3.2).

3.3.1 Chemical analyses of milk and cottage cheese dessert

3.3.1.1 Titratable acidity

The TA, which denotes the total acidity, measures the lactic acid and the apparent acidity of the sample by the titrimetric method described by Bradley, Arnold, Barbano, Semared, Smith and Vines (1992) and Kosikowski and Mistry (1999b). The acidity was determined by titrating 9 ml of a milk sample, or 9 g of cottage cheese dessert sample + 9 ml of distilled water, against 0.1N sodium hydroxide in the presence of phenolphthalein as an indicator. The pink colour that developed marked the end point of the titration. The percentage titratable acidity was calculated using the formula:

$$\% \text{ Titratable acidity} = \frac{V \times N \times ME \text{ of lactic acid}}{\text{weight of sample}} \times 100$$

Where: V = volume of sodium hydroxide used to titrate
N = normality of the sodium hydroxide solution
ME = milli-equivalents of lactic acid (0.09008)

3.3.1.2 pH

The pH value for the milk, cottage cheese and cottage cheese dessert was determined as described by Kosikowski and Mistry (1999b) using a standard electronic pH meter (Beckman Φ32-pH meter).

3.3.1.3 Fat, protein and lactose content of milk

The fat, protein and lactose contents of FFM and SM were determined as outlined by Bradley *et al*. (1992) and by the IDF (1996). The tests were done at Lactolab, Irene, using a Milkoscan (System 4000, Infrared Spectrometer, Denmark).

The method is based on the principle of the absorption of mid-infrared radiation energy at specific wavelengths for each component analysed. The maximum

absorption of the radiation energy by the carbonyl groups in ester linkages of fat molecules is at 5.723 µm; by peptide linkages between amino acids of protein molecules at 6.465 µm and that of the OH-groups in lactose molecules is at 9.610 µm.

3.3.1.4 Lactose content of cottage cheese dessert

High Pressure Liquid Chromatography (HPLC) was used as described by Smit and Nel (1987) to determine the lactose content of cottage cheese dessert samples. The apparatus consists of:

1. Hewlett Packard 3390 A integrator
2. HPLC pump (Anatech, Randburg, South Africa)
3. 20 µl fixed loop
4. Nucleosil; NH_2 guard column
5. Nucleosil-100 (5 mm) NH_2 column (250 x 4 mm)
6. ERC-7525 refractive index detector (Anatech, Randburg, South Africa)

The mobile phase consisted of an 80:20 acetonitrile:water mixture with an applied flow rate of 2 ml/ min. For sample preparation, 5 g of the cheese sample was thoroughly mixed in a stomacher bag, supplied by D. H. Kershaw Co., Benoni, South Africa. A precipitant (sodium tungstate), which precipitates the fat and protein, was added to the cottage cheese dessert sample to make up a final mass of 25 g, followed by homogenisation for approximately 1 min. The prepared mixture was then filtered through Whatman 40 filter paper and then with a syringe (20 µl) filter before being injected into the HPLC apparatus (Smit and Nel, 1987).

3.3.1.5 Fat content and the fat-in-dry matter of cottage cheese dessert

The Pennsylvania Modified Babcock test was used to determine the total fat content and the calculated value of the fat-in-dry matter (FIDM) of the cottage cheese dessert (Bradley *et al*. 1992). The fat content was calculated as follows:

% Fat = reading obtained from the test bottle

$$\% \text{ FIDM} = \frac{\% \text{ Fat} \times 100}{100 - \% \text{ moisture}}$$

3.3.1.6 Protein content of cottage cheese dessert

The crude protein content was determined by the Dumas method (nitrogen combustion analysis method) as described by the AOAC (1995a) and Fox and McSweeny (1998). A nitrogen analyser, model FP 2000 (LECO Africa Pty, Ltd., Kempton Park, S.A.) was used. The nitrogen values obtained were transformed to the percentage protein using the formula:

$$\% \text{ Protein} = \% \text{ Nitrogen} \times 6.38$$

Where: 6.38 is the conversion factor for dairy products.

Based on the theory of this method, the sample is turned into gas by introducing oxygen during combustion. Nitrogen is freed by proteolysis and swept by a CO_2 carrier into a nitrometer where CO_2 is then absorbed in potassium hydroxide. Nitrogen is then measured with a T-cell (gas chromology).

3.3.1.7 Total solids content

3.3.1.7 (a) Total solids in milk

Total solids were determined using a direct forced air oven drying method (Bradley *et al*. 1992; AOAC, 1995b). The value was obtained using the formula:

$$\% \text{ Total solids} = \frac{[(W_2 - W) - B]}{(W_1 - W)} \times 100$$

Where: W = the mass in grams of the empty dish

W_1 = the mass in grams of dish + milk sample

W_2 = the mass in grams of dish + dry milk

B = the mean mass in grams of the blank

3.3.1.7 (b) Total solids in cottage cheese dessert

Total solids in cheese were determined applying the oven drying method (IDF, 1982; Kosikowski and Mistry, 1999b). The total solids were calculated using the formula:

$$\% \text{ Total solids} = \frac{m_2 - m_0 \times 100}{m_1 - m_o}$$

Where: m_0 = the mass in grams of the empty dish

m_1 = the mass in grams of the dish + sample

m_2 = the mass in grams of the dish + dried sample (residue)

3.3.1.8 Moisture content

3.3.1.8 Moisture content and the moisture in fat-free substances of cottage cheese dessert

The moisture content was obtained by subtracting the total solids obtained in subsection 3.3.1.7 (b) from 100 and the moisture in fat-free substances (MIFF's) is a calculated value

$$\% \text{ Moisture} = 100 - \% \text{ Total solids}$$

$$\% \text{ MIFF's} = \frac{\% \text{ moisture} \times 100}{100 - \% \text{ fat}}$$

3.3.1.9 Ash content

3.3.1.9 (a) Ash content of milk

The ash content of the milk was determined by the gravimetric method. Samples were ashed at 550 ^{o}C in a furnace as described by the AOAC (1995c). The % ash was calculated from the formula:

$$\% \text{ Ash} = \frac{*\text{mass of residue} \times 100}{\text{mass of sample}}$$

$$= \frac{W_2\text{-}W}{W_1\text{-}W} \times 100$$

Where: W = the mass of the empty crucible

W_1 = the mass of the crucible + sample

W_2 = the mass of the crucible + ash

* = mass in grams

3.3.1.9 (b) Ash content of cottage cheese dessert

This value was determined according to the gravimetric method as described by Bradley *et al.* (1992), AOAC (1995d), and James (1995) as in subsection 3.3.1.9 (a).

3.3.1.10 Salt content and the salt-in-water of cottage cheese dessert

The salt content was determined by the Mohr titration method (Australian Society of Dairy Technology, 1966; Bradley *et al*. 1992; James, 1995). The test samples were titrated against 0.171N silver nitrate ($AgNO_3$) in the presence of 10 % potassium chromate as an indicator. A visible pale red-brown colour marked the end point of the titration. The salt-in-water (SIW) is a calculated value. The percentage salt was calculated, using the following formula:

$$\% \text{ NaCl} = \frac{\text{ml 0.171 N } AgNO_3 \text{ - 0.15}}{\text{2 (mass of sample in mg's)}} \times 100$$

$$\% \text{ SIW} = \frac{\% \text{ salt}}{\% \text{ moisture}} \times 100$$

3.3.1.11 Total carbohydrates in cottage cheese dessert

The percentage of the total carbohydrates (TC) is a calculated value obtained by difference (James, 1995). Total carbohydrates are expressed as the percentage of the simple sugars, mainly glucose and galactose, formed as a result of the

degradation of lactose as well as sucrose from the added fruit pulps. The percentage total carbohydrates was calculated as follows:

$$\% TC = 100 - \% (moisture + protein + fat + ash)$$

3.3.1.12 Energy value of cottage cheese dessert

The energy value (kJ) was obtained as a calculated value from the overall percentages of the fat, protein and carbohydrate. It is expressed in kiloJoule per gram (kJ/100g) of the dry matter in the sample (James, 1995). Calculations were made according to the following formula:

$$kJ = (\% protein \times 17) + (\% Fat \times 37) + (\% CHO \times 17)$$

Where: numbers 17, 37 and 17 are the Attwater and Bryant general conversion factors of 1900's (James, 1995).

3.3.1.13 Cheese yield

The cheese yield was calculated as the cheese mass per equivalent volume of the initial milk (Kosikowski and Mistry, 1999a)

$$\% Yield = \frac{mass\ (g)\ of\ produced\ cheese \times 100}{initial\ mass\ (g)\ of\ the\ milk}$$

3.3.2 Microbiological analyses of full-fat, skim milk, cottage cheese and cottage cheese dessert

3.3.2.1 Sample preparation

Sampling of milk and cheese was done as described in subsection 3.2.4. A series of serial dilutions of FFM, SM and that of cottage cheese dessert samples, in duplicate, were prepared from 10 ml or g of sample + 90 ml of diluent, as outlined by IDF (1985).

3.3.2.2 Enumeration of microorganisms in milk, cottage cheese and cottage cheese dessert

The total colony count for both milk types (day 1) were done according to IDF (1987). Colonies were counted by using a scientific colony counter (Stuart Scientific CO., UK) and all colony counts were expressed as colony forming units (cfu) per gram of sample.

3.4 SENSORY EVALUATION

The overall quality and acceptability of the FFCCD and SMCCD samples were assessed by a panel of 100 consumers on day 2 only. To evaluate the results, a nine-point Hedonic preference scale was used as shown in Table 3.3 (Meilgaard Civille and Carr (1991).

Table 3.3: Score sheet for the sensory evaluation of cottage cheese dessert. Adapted from Meilgaard *et al*. (1991).

SENSORY EVALUATION OF COTTAGE CHEESE DESSERT

Date……
Name……..

Please taste the four samples from left to right. Evaluate each sample, as to how much you like it by making a mark (x) in the specific blocks. Between samples drink water.

DEGREE OF LIKING	**CODES:**			
	A **E**	**B** **F**	**C** **G**	**D** **H**
Like extremely				
Like very much				
Like moderately				
Like slightly				
Neither like nor dislike				
Dislike slightly				
Dislike moderately				
Dislike very much				
Dislike extremely				

Comments:……
……

Thank you for your participation !!!

3.5 STATISTICAL ANALYSES

Data on analyses (Table 3.2) were statistically analysed using the statistical program: GENSTAT 5 (Payne, 2005). The means, p-values (p = 0.05) and standard deviations were calculated and the least significant differences obtained (Payne, 2005). For the sensory evaluation data, the experiment was designed as a completely randomised design (CRD) with 42 to 56 replicates. Analysis of Variance (ANOVA) for unbalanced data was used to test for differences between % fat, % fruit and % fat x fruit interactions. Treatment means were separated using Fisher's protected t-test least significant difference (LSD) at the 5 % level of significance (Snedecor and Cochran, 1980; Payne, 2005).

CHAPTER 4

RESULTS

4.1 COTTAGE CHEESE DESSERT MANUFACTURING

4.1.1 Fresh milk analysis

Statistically, the full-fat milk (FFM) and skim milk (SM) differed significantly ($p<0.05$) in protein, fat, total solids content and the yield, but there was no significant difference ($p>0.05$) in the lactose and ash content, pH values, titratable acidity (TA) as well as the total colony count (TCC) (Table 4.1). As expected the fat content of the FFM was higher than that of the SM, 3.45 and 0.14 % respectively, and the same trend applied for the total solid content. On the contrary, the protein content, of the SM was higher than that of the FFM at 3.09 and 2.98 % respectively (Table 4.1). A significant difference ($p=0.004$) was recorded for the % yield which was higher for the FFM than for the SM; 28.18 and 19.5 % respectively (Table 4.1).

Table 4.1: Chemical composition, microbiological status and other chemical properties of full-fat milk and skim milk used for the manufacture of full-fat and skim milk cottage cheese dessert

Component [1]	Unit	FFM [2]	SM [3]	F-probability
Fat	%	3.45 ± 0.30 [4]	0.14 ± 0.01	**0.003** [7]
Protein	%	2.98 ± 0.02	3.09 ± 0.01	**< 0.001**
Lactose	%	4.55 ± 0.25	4.87 ± 0.04	0.095
Ash	%	0.75 ± 0.07	0.68 ± 0.03	0.232
Total solids	%	11.96 ± 0.04	8.66 ± 0.17	**< 0.001**
TA [5]	%	0.15 ± 0.01	0.14 ± 0.01	0.101
pH		6.69 ± 0.04	6.67 ± 0.06	0.715
TCC [6]	Log_{10}cfu/ml	4.69 ± 0.07	4.61 ± 0.08	0.241
Yield	%	28.18 ± 0.32	19.5 ± 1.10	**0.004**

[1] All components are expressed as percentages (%) except for the pH and the TCC (cfu/ml); [2] (FFM) Full-fat milk; [3] (SM) Skim milk; [4] All values are the mean ± the standard deviation; [5] (TA) Titratable Acidity; [6] (TCC) Total Colony count; [7] F-probability values in bold showed a significant difference ($p<0.05$)

4.1.2 Cottage cheese: changes in the pH and titratable acidity values during manufacture from day 1 to day 3

The day to day effect did not have a significant difference on the pH during the three days of cottage cheese manufacturing for both cheeses (Table 4.2). However, it was noticed that the pH decreased over time with day 1 having the highest value 6.69 as compared to day 3 with the lowest, 4.83. The % TA did not differ significantly at day 1 (p=0.230), day 2 (p=0.925) and day 3 (p=0.132) between the two cottage cheeses. It was however, observed that the % TA increased from day 1 (milk), to day 2 (coagulum) and then decreased from day 2 to day 3 (curd) and this was observed for the two cottage cheese types (FFCC; full-fat cottage cheese and SMCC; skim milk cottage cheese). The % TA, at day 3, SMCC was higher than that of the full-FFCC; 0.58 and 0.53 % respectively (Table 4.2).

Table 4.2: Changes in the pH and titratable acidity values of cottage cheese during manufacture from day 1 to day 3

Day [1]	Treatment effect: pH			Treatment effect: % TA		
	FFCC[2]	SMCC[3]	F-probability[5]	FFCC	SMCC	F-probability
1	6.69 ± 0.04	6.67 ± 0.06[4]	0.715	0.15 ± 0.01	0.15 ± 0.01	0.230
2	4.51 ± 0.01	4.54 ± 0.02	0.091	0.64 ± 0.04	0.64 ± 0.04	0.925
3	4.83 ± 0.59	4.38 ± 0.08	0.321	0.53 ± 0.02	0.58 ± 0.04	0.132

1 Samples taken from the same batch for each cottage cheese type over a period of three days (day 1 = milk, day 2 = coagulum and day 3 = curd)
2 (FFCC) Full-fat cottage cheese
3 (SMCC) Skim milk cottage cheese
4 All values are expressed as mean values ± standard deviation
5 F-probability values in bold showed a significant difference (p<0.05)

4.2 COTTAGE CHEESE DESSERT: PHYSICO-CHEMICAL AND MICROBIOLOGICAL PARAMETERS

4.2.1 Physico-chemical parameters

4.2.1.1 Lactose, fat, fat-in-dry-matter and the protein content

The results obtained from the analyses of lactose, fat, % fat-in-dry-matter (FIDM) as well as the protein content of the full-fat cottage cheese dessert (FFCCD) and skim milk cottage cheese dessert (SMCCD) are reported in Table 4.3, elaborating on the effects of the fat, fruit content as well as the fat and the fruit interaction on these parameters.

The lactose content was significantly affected by the fruit content ($p=0.042$) and showed a decline with an increase in the fruit content, 0 to 30 %, with the control having the highest value of 3.4 % and the 30 % fruit component with a value of 2.71 %. The fat ($p=0.716$) and the fat and the fruit interaction ($p=0.062$) did not have a significant effect on the lactose content of the FFCCD and the SMCCD which were found to have similar fat content values of 3.04 and 2.98 % for the two respective dessert types. With the fat x fruit interaction, the control samples for the two desserts were found to contain higher levels of the lactose content, 3.63 and 3.27 % followed by the 10 % treatments with the 20 and 30 % treatments having the lowest values.

The effect of the overall fat ($p<0.001$) and that of the fat x fruit interaction ($p=0.007$) influenced the fat content of the two desserts types but no significant fruit effect ($p=0.079$) was recorded. Significant fat content values were obtained for the FFCCD, 9.03 % as compared to 0.13 % for the SMCCD. Similarly, the fat x fruit interaction affected the fat content which showed a decline from the control to the 30 % treatment for the FFCCD but no particular trend for the SMCCD. There was no significant effect on the fat content by the fruit ($p>0.079$). The % FIDM was significantly affected by the overall fat ($p<0.001$) with the FFCCD having higher values (36.02 %) than the SMCCD, (0.59 %). However, with the effect of the fruit ($p<0.001$) it tended to decrease with an increase in the fruit content of the two dessert types from the control to the 30 % treatment. The % FIDM was also, significantly affected by the fat x fruit interaction ($p<0.001$) with the control samples having higher % FIDM than the other three treatment for both the FFCCD and the SMCCD.

Table 4.3: The effect of fat, fruit and fat x fruit interaction on the lactose, fat, protein content and the fat-in-dry matter of the full-fat and skim milk cottage cheese dessert

Effect	Physico-chemical parameters			
Fat content	**% Lactose**	**% Fat**	**% FIDM[5]**	**% Protein**
FF[1]	3.043± 0.65[2]	9.03 ± 1.49	36.02 ± 7.64	7.12 ±1.19
LF[2]	2.98 ± 0.28	0.13 ± 0.03	0.59 ± 0.00	8.07 ± 2.00
F-probability	0.716	**< 0.001[4]**	**< 0.001**	0.064
Fruit content				
Control	3.45 ± 0.24	5.21 ± 5.69	22.67 ± 24.45	8.88 ± 1.67
10%	3.12 ± 0.71	4.73 ± 5.12	19.61 ± 20.96	7.87 ± 1.66
20%	2.77 ± 0.24	4.37 ± 4.69	16.65 ± 17.84	7.44 ± 1.21
30%	2.71 ± 0.25	4.00 ± 4.30	14.30 ± 15.22	6.18 ± 1.20
F-probability	**0.042**	0.079	**< 0.001**	**0.009**
Fat x Fruit content interaction				
FF x Control	3.63 ± 0.11	10.30 ± 1.69	44.77 ± 5.46	8.21 ± 0.74
FF x 10%	3.20 ± 1.10	9.34 ± 1.33	38.60 ± 3.95	7.26 ± 0.94
FF x 20%	2.79 ± 0.24	8.58 ± 1.21	32.65 ± 5.26	7.22 ± 1.13
FF x 30%	2.55 ± 0.13	7.87 ± 1.10	28.06 ± 3.35	5.78 ± 0.71
LF x Control	3.27 ± 0.17	0.12 ± 0.03	0.58 ± 0.00	9.56 ± 2.24
LF x 10%	3.03 ± 0.14	0.12 ± 0.03	0.61 ± 0.00	8.48 ± 2.21
LF x 20%	2.74 ± 0.30	0.15 ± 0.03	0.65 ± 0.00	7.66 ± 1.50
LF x 30%	2.86 ±0.25	0.13 ± 0.03	0.55 ± 0.00	6.57 ± 1.20
F-probability	0.621	**0.007**	**< 0.001**	0.899

1. (FF) Full-fat
2. (LF) Low-fat
3. All values are expressed as mean values ± standard deviation
4. F-probability values in bold showed a significant difference ($p<0.05$)
5. (FIDM) Fat-in-dry matter

Statistically, there was no significant effect by the fat ($p>0.05$) and the fat x fruit interaction ($p>0.05$) on the protein content of the FFCCD and the SMCCD. The two desserts had almost similar values of 7.12 and 8.07 % for the FFCCD and SMCCD, respectively (Table 4.3). The effect of the fruit only, was significant ($p=0.009$) where the control sample was found to have higher levels of the protein content, (8.8 %) followed by all other treatments with the 30 % fruit component having the least. Thus the protein content decresed with an increase in the fruit content and the same trend was observed with the fat x fruit interaction effect on the protein content.

4.2.1.2 Ash, total solids, moisture content and the moisture in fat-free substances

The ash content of the FFCCD and the SMCCD did not differ statistically. A significant effect of the fruit content ($p<0.001$) on the ash content was recorded as it showed an increase in the ash content with an increment in the fruit content of the four treatments (0, 10, 20 and 30 %) (Table 4.4). The fat and the fat x fruit interaction did not have any significant effect ($p>0.05$) on the ash content. However, the interaction showed the same trend with the control having less ash that the other three treatments. Similarly, the fruit content significantly affected the total solids content ($p<0.001$) of the FFCCD and SMCCD where the total solid content increased with an increase in the fruit content. These solids were also significantly affected by the overall fat content ($p<0.001$) but there was no significant effect on the total solids by the fat and fruit effect ($p>0.05$).

Significant effects of the overall fat ($p<0.001$) and the fruit content ($p<0.001$) were recorded on the moisture content of the two dessert types. The fat influenced the moisture content which tended to increase with a decrease in the fat content with FFCCD having a value of 74.61 % as compared to the SMCCD with a higher value of 78.76 %. The fruit effect showed a decrease in the moisture content with an increase in the fruit content from 0 to 30 %.

Table 4.4: The effect of fat, fruit and fat x fruit interaction on the ash, total solids, moisture content and the moisture in fat-free substances of full-fat and skim milk cottage cheese dessert

Effect	Physico-chemical parameters			
Fat content	**% Ash**	**% Total solids**	**% Moisture**	**% MIFF's[5]**
FF[1]	1.24 ± 0.11[3]	25.39 ± 2.67	74.61 ± 2.67	82.04 ± 3.49
LF[2]	1.30 ± 0.18	21.24 ± 2.93	78.76 ± 2.93	78.66 ± 2.94
F- probability	0.110	**< 0.001[4]**	**< 0.001**	**0.001**
Fruit content				
Control	1.13 ± 0.08	20.72 ± 3.15	79.28 ± 3.15	83.76 ± 2.99
10%	1.23 ± 0.14	22.07 ±3.20	77.93 ± 3.20	81.49 ± 3.30
20%	1.27 ± 0.12	24.48 ± 2.60	75.52 ± 2.60	79.03 ± 2.40
30%	1.43 ± 0.14	26.00 ±2.84	74.00 ± 2.84	77.12 ± 1.96
F-probability	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**
Fat x Fruit content interaction				
FF x Control	1.12 ± 0.05	22.96 ± 1.58	77.05 ± 1.58	85.90 ± 1.15
FF x 10%	1.20 ± 0.11	24.18 ± 2.31	75.82 ± 2.31	83.65 ± 1.89
FF x 20%	1.16 ± 0.13	26.38 ± 1.71	73.62 ± 1.73	80.52 ± 2.17
FF x 30%	1.36 ± 0.13	28.04 ± 2.26	71.96 ± 2.26	78.10 ± 2.07
LF x Control	1.13 ± 0.12	18.48 ± 2.70	81.52 ± 2.70	81.86 ± 2.69
LF x 10%	1.26 ± 0.11	19.96 ± 2.64	80.04 ± 2.64	79.34 ± 3.12
LF x 20%	1.28 ± 0.15	22.57 ± 1.72	77.43 ± 1.72	77.54 ± 1.74
LF x 30%	1.50 ± 0.14	23.95 ± 1.56	76.05 ± 1.60	76.14 ± 1.56
F- probability	0.552	0.989	0.989	0.704

1. (FF) Full-fat
2. (LF) Low-fat
3. All values are expressed as mean values ± standard deviation
4. F-probability values in bold showed a significant difference ($p<0.05$)
5. (MIFFS's) Moisture in fat-free substances

The % MIFF's was significantly affected by the overall fat content ($p=0.001$) of the two dessert types with the full-fat cottage cheese dessert having higher values as well as the fruit ($p<0.001$) which, similarly to the moisture content, showed a decrease with an increase in the fruit content from 0 to 30 %. There was however, no significant effect by the fat x fruit interaction ($p=0.704$).

4.2.1.3 Salt content, salt-in-water, total carbohydrates and the energy value

Salt, added during manufacturing, as part of a preservative effect, was not affected by the fat ($p=0.479$) nor the fat x fruit interaction ($p=0.475$), but by the fruit ($p=0.004$) (Table 4.5). On the contrary, the % salt-in-water (SIW) was not affected at all by the fat ($p=0.106$), the fruit ($p=0.77$) as well as the fat x fruit interaction ($p=0.562$). The % SIW values remained similar and ranged from 0.07 to 0.09 %.

The % total carbohydrates (TC), a calculated value, was significantly affected by the fat ($p=0.003$) and the fruit ($p<0.001$) but not by the fat x fruit interaction ($p>0.05$). The carbohydrate value of the SMCCD; 11.75 % was higher than that of the FFCCD; 7.70 %. The effect of the fruit showed an increase in the % TC with an increment in the fruit content from 0 to 30 % and a similar trend was found for each dessert type as affected by the fat x fruit interaction effect.

The FFCCD showed a higher energy value, 582.7 kJ than that of the SMCCD, 330.50 kJ thus a significant effect by the fat content ($p<0.001$). The same was recorded for the fruit effect ($p=0.007$) on the energy value which showed a tendency to increase with an increase in the fruit content from 0 to 30 % but there was no effect by the fat x fruit interaction.

Table 4.5: The effect of fat, fruit and fat x fruit interaction on the salt content, salt-in-water, total carbohydrates and the energy value of the full-fat and skim milk cottage cheese dessert

Effect	Physico-chemical parameters			
Fat content	**% Salt**	**% SIW[4]**	**% Total carbohydrates**	**Energy value**
FF[1]	0.06 ± 0.01[3]	0.08 ± 0.01	7.70 ± 4.21	582.7 ± 44.26
LF[2]	0.06 ± 0.01	0.07 ±0.01	11.75 ± 4.52	330.5 ± 52.56
F-probability	0.479	0.106	**0.003[5]**	**< 0.001**
Fruit content				
Control	0.06 ± 0.01	0.08 ± 0.01	5.50 ± 3.8	432.8 ±160.85
10%	0.06 ± 0.01	0.08 ± 0.01	7.62 ± 3.92	434.7 ± 136.60
20%	0.06 ± 0.01	0.07 ± 0.01	11.39 ± 3.60	466.4 ± 148.60
30%	0.05 ± 0.00	0.07 ± 0.01	14.39 ± 2.16	492.5 ± 131.02
F-probability	**0.004**	0.77	**< 0.001**	**0.007**
Fat x Fruit content interaction				
FF x Control	0.07 ± 0.01	0.09 ± 0.01	3.32 ± 0.35	573.8 ± 53.67
FF x 10%	0.06 ± 0.01	0.08 ± 0.01	5.15 ± 0.89	554.8 ± 36.35
FF x 20%	0.05 ± 0.01	0.07 ± 0.01	9.30 ± 3.18	595.4 ± 36.33
FF x 30%	0.05 ± 0.00	0.07 ± 0.00	13.03 ± 1.26	606.9 ± 53.34
LF x Control	0.06 ± 0.00	0.07 ± 0.01	7.68 ± 4.69	291.9 ± 46.93
LF x 10%	0.06 ± 0.01	0.08 ± 0.01	10.09 ± 4.39	314.7 ± 45.96
LF x 20%	0.06 ± 0.01	0.07 ± 0.01	13.48 ± 3.04	337.5 ± 63.42
LF x 30%	0.05 ± 0.00	0.07 ± 0.01	15.75 ± 2.12	378.0 ± 28.05
F-probability	0.475	0.562	0.910	0.412

1. (FF) Full-fat
2. (LF) Low-fat
3. All values are expressed as mean values ± standard deviation
4. (SIW) Salt-in-water
5. F-probability values in bold showed a significant difference ($p<0.05$)

4.2.2 Changes in the pH and the titratable acidity at day 1, 7, 14 and 21 as affected by the fat, fruit, day as well as all their interactions

4.2.2.1 pH

The specific effects and the interaction effects on the pH of FFCCD and SMCCD are summarized in Table 4.6. The fruit and the day parameters had a significant effect ($p>0.05$) on the pH of both dessert types. With the fruit effect

(p=0.021), the pH showed a slight decrease with an increase in the fruit content from 0 to 30 % fruit. The day-to-day effect (p<0.001) significantly affected the pH and the values showed an increase on a weekly basis with day 1 having the least, pH 4.37 and day 21 the greatest, pH 4.76. The fat and none of the interactions (fat/fruit, day/fat and day/fat/fruit) had any effect on the pH. Nonetheless, the same tendencies were found in all interactions where the pH decreased with an increase in the fat content and increased by day during storage for three weeks.

4.2.2.2 Titratable acidity

During the three week storage period, the fat and the fruit and the day significantly affected the percentage titratable acidity (TA) (Table 4.7). The TA was significantly affected by the fat (p<0.001), with the SMCCD having a higher percentage value of 0.57 than the FFCCD, 0.51 respectively. The significant effect of the fruit (p<0.001) had a tendency to decrease the TA with an increase in the % fruit from 0 to 30 % and on the contrary the effect of the day (p<0.001) on the TA increased it daily over a period of three weeks from 0.50 to 0.56 % (Table 4.7).

All the interactions (fat x fruit, day x fat, day x fruit and day x fat x fruit) effects did not significantly affect the TA and thus most values were almost similar. However, there was a trend where in both treatments, the TA tended to decrease with an increase in the % fruit but increased over a period of time.

Table 4.6: The effect and interaction effects of specific parameters on the pH of the full-fat and skim milk cottage cheese dessert during storage for 21 days at 4 °C

Effect and the interaction effects					**F-probability**
Fat [1] FF[2] LF[3]	 4.54 ± 0.16[4] 4.57 ± 0.18				0.115
Fruit	Control 4.59 ± 0.16	10% 4.56 ± 0.15	20% 4.54 ± 0.17	30% 4.52 ± 0.19	**0.021**[5]
Fat x Fruit FF LF	Control [6] 4.56 ± 0.15 4.62 ± 0.16	10% 5.56 ± 0.14 4.56 ± 0.17	20% 4.52 ± 0.17 4.55 ± 0.18	30% 4.51 ± 0.19 4.53 ± 0.19	0.786
Day	1[7] 4.37 ± 0.09	7 4.48 ± 0.14	14 4.59 ± 0.04	21 4.76 ± 0.04	**< 0.001**
Day x Fat FF LF	1 4.37 ± 0.09 4.37 ± 0.10	7 4.48 ± 0.13 4.49 ± 0.15	14 4.56 ± 0.04 4.62 ± 0.02	21 4.74 ± 0.04 4.77 ± 0.03	0.664
Day x Fruit 1 7 14 21	Control 4.45 ± 0.08 4.52 ± 0.13 4.61 ± 0.21 4.79 ± 0.04	10% 4.41± 0.07 4.49 ± 0.15 4.59 ± 0.04 4.75 ± 0.03	20% 4.34 ± 0.08 4.47 ± 0.15 4.59 ± 0.03 4.75 ± 0.04	30% 4.29 ± 0.07 4.46 ± 0.15 4.58 ± 0.03 4.47 ± 0.04	0.744
Day x Fat x Fruit **FF** 1 7 14 21 **LF** 1 7 14 21	Control 4.41 ±0.04 4.51 ±0.10 4.57 ± 0.13 4.77 ± 0.00 4.48 ± 0.10 4.52 ± 0.18 4.65 ± 0.01 4.8 ± 0.05	10% 4.44 ± 0.06 4.48 ± 0.16 4.56 ± 0.03 4.74 ± 0.03 4.37 ± 0.06 4.49 ± 0.17 4.62 ± 0.03 4.76 ± 0.02	20% 4.34 ± 0.08 4.46 ± 0.16 4.56 ± 0.03 4.73 ± 0.05 4.35 ± 0.09 4.47 ± 0.17 4.61 ± 0.02 4.76 ± 0.02	30% 4.27 ± 0.06 4.46 ± 0.18 4.55 ± 0.02 4.73 ± 0.06 4.30 ± 0.09 4.46 ± 0.48 4.61 ± 0.01 4.75 ± 0.02	0.996

1. Contents are expressed as percentages
2. (FF) Full-fat
3. (LF) Low-fat
4. All values are expressed as mean values ± standard deviation
5. F-probability values in bold showed a significant difference ($p<0.05$)
6. (Control, 10 %, 20 % and 30 %) Treatments
7. (1,7,14 and 21) Days

Table 4.7: The effect and interaction effects of specific parameters on the titratable acidity of full-fat and skim milk cottage cheese dessert during storage for 21 days at 4 °C

Effect and the interaction effects					**F- probability [3]**
Fat [1] FF[2] LF[3]	 0.51 ± 0.06 [4] 0.57 ± 0.09				**< 0.001[5]**
Fruit	Control[6] 0.60 ±0.07	10% 0.55 ± 0.07	20% 0.51± 0.07	30% 0.47 ± 0.06	**< 0.001**
Fat x Fruit FF LF	Control 0.56 ±0.04 0.64 ± 0.07	10% 0.52 ± 0.05 0.58 ± 0.08	20% 0.48 ± 0.03 0.55 ± 0.08	30% 0.45 ± 0.03 0.49 ± 0.07	0.957
Day	1[7] 0.50 ± 0.07	7 0.53 ± 0.09	14 0.54 ± 0.07	21 0.56 ± 0.08	**< 0.001**
Day x Fat FF LF	1 0.45 ± 0.04 0.54 ± 0.06	7 0.50 ± 0.06 0.55 ± 0.11	14 0.51 ± 0.05 0.57 ± 0.09	21 0.54 ± 0.05 0.58 ±0.10	0.395
Day x Fruit 1 7 14 21	Control 0.56 ± 0.05 0.58 ± 0.04 0.61 ± 0.08 0.65 ± 0.07	10% 0.51 ± 0.07 0.55 ± 0.10 0.56 ± 0.04 0.58 ± 0.04	20% 0.49 ± 0.06 0.51 ± 0.11 0.52 ± 0.05 0.53 ± 0.06	30% 0.45 ± 0.05 0.47 ± 0.09 0.47 ± 0.05 0.48 ± 0.04	0.975
Day x Fat x Fruit **FF** 1 7 14 21 **LF** 1 7 14 21	Control 0.51 ± 0.01 0.58 ± 0.04 0.56 ±0.02 0.60 ± 0.04 0.60 ± 0.02 0.58 ± 0.04 0.66 ± 0.09 0.69 ± 0.06	10% 0.46 ± 0.04 0.52 ± 0.01 0.54 ± 0.01 0.57 ± 0.01 0.56 ± 0.06 0.58 ± 0.14 0.57 ± 0.05 0.59 ± 0.06	20% 0.44 ± 0.01 0.47 ± 0.02 0.49 ± 0.01 0.51 ± 0.03 0.53 ± 0.05 0.55 ± 0.16 0.54 ± 0.06 0.55 ± 0.08	30% 0.41 ± 0.02 0.44 ± 0.02 0.44 ± 0.03 0.48 ± 0.03 0.48 ± 0.05 0.50 ±0.13 0.49 ± 0.06 0.49 ± 0.06	0.747

1. Contents are expressed as percentages
2. (FF) Full-fat
3. (LF) Low-fat
4. All values are expressed as mean values ± standard deviation
5. F-probability values in bold showed a significant difference ($p<0.05$)
6. (Control, 10 %, 20 % and 30 %) Treatments
7. (1,7,14 and 21) Days

4.2.3 Microbiological quality and shelf life: Total colony count at day 1, 7, 14 and 21 as affected by the fat, fruit, day as well as all their interactions

The total colony count (TCC) of the two cottage cheese dessert types with the respective treatments was significantly affected by the fat ($p<0.001$), the day ($p<0.001$) as well as the day/fat interaction ($p<0.001$) (Table 4.8). The fat effect showed that SMCCD had an overall higher TCC, (7.28 log cfu/g) than the FFCCD, (6.84 log cfu/g) (Table 4.8).

The day effect on the TCC showed that these values increased significantly on a day-to-day basis over a period of three weeks (21 days) where day 1 had a value of 6.10 log cfu/g as compared to 7.79 log cfu/g at day 21. The same effect was observed with the day x fruit interaction effect ($p<0.001$) with the SMCCD having higher values than the FFCCD on each day.

No significant effects were determined on the TCC by the fruit, fat x fruit, day x fruit as well as the day x fat x fruit interaction. However the same tendencies were valid where the TCC decreased with an increase in the % fruit but increased over a period of time.

Table 4.8: The effect and interaction effects of specific parameters on the total colony count (log cfu/g) of the full-fat and skim milk cottage cheese dessert during storage for 21 days at 4 °C

Effect and the interaction effects					F- probability
Fat [1] FF[2] LF[3]	 6.84± 0.67 [4] 7.28 ± 0.78				**< 0.001**[5]
Fruit	Control[6] 7.16 ± 0.79	10% 7.06 ± 0.77	20% 7.05 ± 0.75	30% 6.98 ± 0.75	0.108
Fat x Fruit FF LF	Control 6.91 ± 0.68 7.41 ± 0.84	10% 6.85 ± 0.70 7.21 ± 0.80	20% 6.94 ± 0.69 7.25 ± 0.78	30% 6.77 ± 0.69 7.20 ± 0.77	0.932
Day	1 6.10 ± 0.43	7 6.80 ± 0.21	14 7.56 ± 0.27	21 7.79 ± 0.45	**< 0.001**
Day x Fat FF LF	1[7] 5.82 ± 0.14 6.39 ± 0.43	7 6.71 ± 0.10 6.88 ± 0.77	14 7.42 ± 0.07 7.71 ± 0.31	21 7.42 ± 0.10 8.17 ± 0.33	**< 0.001**
Day x Fruit 1 7 14 21	Control 6.16 ± 0.04 6.87 ± 0.23 7.68 ± 0.32 7.91 ± 0.51	10% 6.10 ± 0.46 6.82 ± 0.21 7.47 ± 0.18 7.87 ± 0.51	20% 6.11 ± 0.45 6.78 ± 0.22 7.58 ± 0.30 7.72 ± 0.44	30% 6.04 ± 0.47 6.71 ± 0.70 7.50 ± 0.29 7.68 ± 0.43	0.982
Day x Fat x Fruit **FF** 1 7 14 21 **LF** 1 7 14 21	Control 5.89 ± 0.10 6.79 ± 0.05 7.49 ± 0.03 7.46 ± 0.10 6.44 ± 0.49 6.96 ± 0.32 7.87 ± 0.37 8.35 ± 0.19	10% 5.81 ± 0.20 6.73 ± 0.04 7.44 ± 0.02 7.42 ± 0.12 6.39 ± 0.50 6.91 ± 0.30 7.51 ± 0.27 8.32 ± 0.14	20% 5.82 ± 0.14 6.72 ± 0.03 7.39 ± 0.02 7.42 ± 0.12 6.39 ± 0.48 6.84 ± 0.33 7.76 ± 0.34 8.02 ± 0.45	30% 5.76 ± 0.14 6.61 ± 0.51 7.3 ± 0.02 7.38 ± 0.11 6.32 ± 0.55 6.81 ± 0.25 7.68 ± 0.33 7.97 ± 0.44	0.924

1. Contents are expressed as percentages
2. (FF) Full-fat
3. (LF) Low-fat
4. All values are expressed as mean values ± standard deviation
5. F-probability values in bold showed a significant difference ($p<0.05$)
6. (Control, 10 %, 20 % and 30 %) Treatments
7. (1,7,14 and 21) Days

4.3 SENSORY EVALUATION

Sensory evaluation was done on day 1 only on freshly manufactured cottage cheese desserts. The statistical analysis showed that there were significant effects by the fat content ($p<0.001$), fruit content ($p<0.001$) and the fat x fruit interaction ($p=0.003$) on the sensory evaluation scores as shown in Table 4.9, Table 4.10 and Figure 4.1. The fat effect had an influence on the preference of the two dessert types where the FFCCD had a higher rating score of 6.86 than the SMCCD with a 5.35 score.

The fruit effect showed that the rating score increased with an increase in the % fruit added thus an increase from 0 to 30 % treatments and this denotes preference based on the sweetness of the fruit. The same trend was observed for the two dessert types as affected by the fat x fruit interaction with the FFCCD having higher scores, (5.59 to 7.31) than the SMCCD, (with the 4.26 to 6.82) score based on the % fruit added (0 – 30 % treatment).

Figure 4.1 shows the distribution of hedonic preference scale ratings for each sample for the two cottage cheese dessert types as well as the number of people out of a hundred consumer panelists who tasted the different samples. Considering the 0 % treatment for both desserts, the FFCCD was liked the most as compared to the 0 % SMCCD. The number of occurrences based on a percentage, was 22.45 % for the former and 5.88% for the latter, respectively. The 10 % FFCCD treatments were liked very much as compared to their counterpart, 10 % SMCCD which was liked moderately. The 20 % treatments, for the two dessert types were liked moderately whereas, the two 30 % treatments were both liked very much as seen from their higher scores. In general, there seems to be a trend of increased scores from 0 to 30 % treatment for the two dessert types.

Table 4.9: Hedonic scores of sensory evaluation of full-fat and skim milk cottage cheese dessert

Effect and the interaction effects	Score [1]
Fat	
FF[2]	6.86 a [4]
LF[3]	5.35 b
F-probability	**<.001**[5]
Fruit content	
Control	4.93 c
10%	5.90 c
20%	6.63 b
30%	7.07 a
F- probability	**<.001**
Fat x Fruit content interaction	
FF x Control	5.59 b
FF x 10%	7.21 a
FF x 20%	7.36 a
FF x 30%	7.31 a
LF x Control	4.26 c
LF x 10%	4.55 c
LF x 20%	5.88 b
LF x 30%	6.82 a
F-probability	**0.003**

1. The hedonic score ranges between 1 and 9 where 1 is the minimum score (dislike extremely) and 9 is the maximum (like extremely)
2. (FF) Full-fat
3. (LF) Low-fat
4. Means per column followed by a different letter were significantly different at the 5 % level
5. F-probability values in bold showed a significant difference ($p \leq 0.05$)

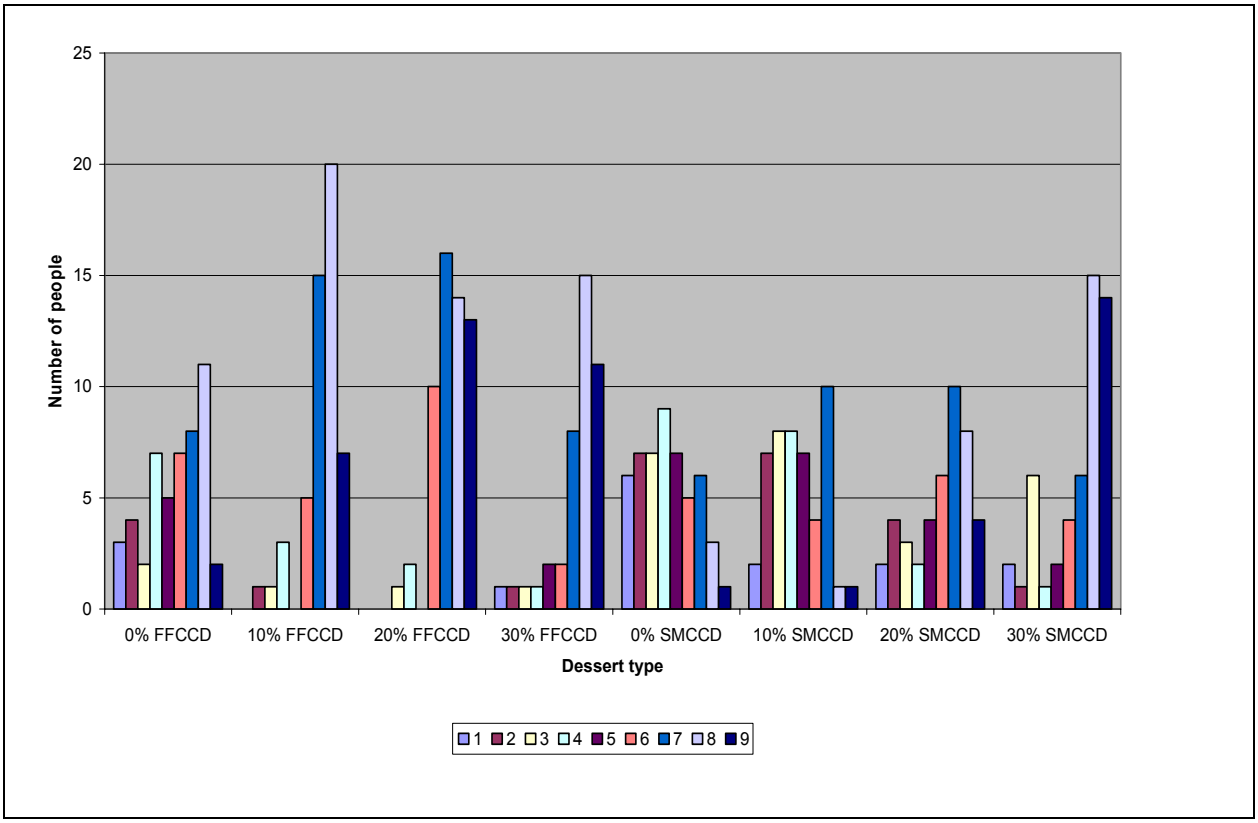
Table 4.10: Summarised results of the hedonic score-ratings for the full-fat and skim milk cottage cheese dessert

Dessert type	Code	No. of occurrences/ No. of people who tested the sample	Hedonic Score Ratings[1]									
			1	2	3	4	5	6	7	8	9	
0% FFCCD[2]	**A**	49	3	4	2	7	5	7	8	11	2	49
		%	6.12	8.16	4.08	14.29	10.20	14.29	16.33	22.45	4.08	
10% FFCCD	**B**	52	0	1	1	3	0	5	15	20	7	52
		%	0.00	1.92	1.92	5.77	0.00	9.62	28.85	38.46	13.46	
20% FFCCD	**C**	56	0	0	1	2	0	10	16	14	13	56
		%	0.00	0.00	1.79	3.57	0.00	17.86	28.57	25.00	23.21	
30% FFCCD	**D**	42	1	1	1	1	2	2	8	15	11	42
		%	2.38	2.38	2.38	2.38	4.76	4.76	19.05	35.71	26.19	
0% SMCCD[3]	**E**	51	6	7	7	9	7	5	6	3	1	51
		%	11.76	13.73	13.73	17.65	13.73	9.80	11.76	5.88	1.96	
10% SMCCD	**F**	49	2	7	8	8	7	4	10	1	1	48
		%	4.08	14.29	16.33	16.33	14.29	8.16	20.41	2.04	2.04	
20% SMCCD	**G**	43	2	4	3	2	4	6	10	8	4	43
		%	4.65	9.30	6.98	4.65	9.30	13.95	23.26	18.60	9.30	
30% SMCCD	**H**	51	2	1	6	1	2	4	6	15	14	51
		%	3.92	1.96	11.76	1.96	3.92	7.84	11.76	29.41	27.45	
		393	16	25	29	33	27	43	79	87	53	
		%	4.07	6.36	7.38	8.40	6.87	10.94	20.10	22.14	13.49	

[1]The hedonic score-ratings ranges between 1 and 9 where 1 is the minimum score (dislike extremely) and 9 is the maximum (like extremely);

[2] (FFCCD) Full-fat cottage cheese dessert

[3] (SMCCD) Skim milk cottage cheese desserts



Score-ratigs: (1) Dislike extremely; (2) Dislike very much; (3) Dislike moderately; (4) Dislike slightly; (5) Neither like nor dislike; (6) Like slightly; (7) Like moderately; (8) Like very much; (9) Like extremely

Figure 4.1: Distribution of hedonic score-ratings for the full-fat cottage and skim milk cottage cheese dessert as illustrated in a histogram with ratings for each score per sample (n = 100 consumers)

CHAPTER 5

DISCUSSION

The lower fat content of the skim milk (SM) is due to the initial milk separation of the FFM (full-fat milk) and this inversely affected the protein content with SM having higher values than the FM. The fat and protein ratios are interlinked as they form a major fraction of the total solids (Van Boekel, 1993). The higher the percentage of one of the components, the lower the other. Thus, the total solids were at the end lower for the SM and higher for the FM.

The composition of milk used in the current study could be compared with that found in studies conducted by Smit *et al.* (1998b). In this study, differences were found in the moisture and the fat content, but not for the protein, lactose and the ash content in the two milk types. In other studies, differences in the initial milk composition are attributed to the geographical area , different animals (species) and milking different times (Galloway & Crawford, 1985).

During cottage cheese manufacturing, over a three day period, it was found that the coagulum of the skim milk cottage cheese (SMCC) was less firm than that of the full-fat cottage cheese (FFCC) and this is due to the protein structure of the cottage cheese. The curd drainage time was *ca* 24 h for the SMCC and a longer period for the FFCC with a further 6 h period till the cheese cloths had a smooth surface. The SMCC coagulum drained at a faster rate and this could be atributed to the finer curd particles, in conjuction with the minimal fat content in the milk, and on the contrary, the long period of drainage for the FFCC can be ascribed to the blockage of the cheese cloths by the milk fat particles. The processing method and the results thereof correspond well with those obtained in the original flow processes described by Winwood (1983); Shaw (1986); Scott (1998) and Galloway (1995).

The day-to-day effect during manufacturing did not affect the pH and the titratable acidity (TA) from day 1 to day 3 significantly. However, a trend was observed where the pH declined over time from the milk to the coagulum from 6.69 to 4.83 for the full-fat cottage cheese range and 6.67 to 4.38 for the skim

milk cottage cheese range . This decline could be attributed to microbial activity at an early stage with the formation of lactic acid between day 1 and day 2. Stabilisation in pH between day 2 and day 3 may be as a result of the inhibition of lactic acid bacteria by the low pH. However, in most types of ripened cheeses the degradation of milk components often result in the formation of neutral metabolites which may cause a shift in pH resulting in its increase. In this case it could be seen with an increase from day 2 to day 3 (Scott, 1998).

During the same period, the analysis of the TA showed an increase from day 1 to day 2 and a decrease from day 2 to day 3 . The decrease in TA between day 2 and day 3 may be due to the continued whey loss which leads to protein loss (Scott 1998). The pH and titratable acidity values obtained in the current study correlates with literature values of Shaw (1986) with pH values in the range between 4.3 and 5.0 and increased titratable acidity values between 0 and 0.06%.

The yield from the two cottage cheese types differed significantly. FFM produced cottage cheese with a higher yield of 28.18 % than that of the SM with 19.5 %. These values correlated with those cited by Kosikowski & Mistry (1999a) whereby the FFM gave approximately 25 % cheese yield and the SM approximately 17.5 %. The higher yield of the FFCC is attributed to the high solids content of the FFM used in cheesemaking.

Analysis of the full-fat cottage cheese (FFCCD) and skim milk cottage cheese (SMCCD) revealed results (proximate analysis, physico-chemical, microbiological as well as sensory evaluation) which were affected by the fat, fruit, fat x fruit interaction and during storage the effects included those of the day, day x fat, day x fruit as well as day x fat x fruit interactions.

The mean lactose content value in this study was ***ca*** 3.04 % for the FFCCD and 2.98 % for the SMCCD. This value can be compared to literature values which

vary between 2 and 4.85 % (Koth & Richter, 1989; Smit *et al*. 1998b). According to Scott (1998), the determination of lactose in cheesemaking is often not regarded as essential since most, or all of it, is degraded within a short period of time to form lactic acid. Lactose is depleted within 24 h of cheese manufacturing in most cheese types, but in cottage cheeses, which are classified as fresh, it might still be present at percentages of 1 to 2 %. Fox, McSweeny, Cogan and Guinee (2004b) and Fox & McSweeny (1998), reported that the residual lactose content in cheese is affected by the inhibitory level of the NaCl, added to the cheese during manufacturing.

The effect of the % fat on the overall fat content of the FFCCD and SMCCD is due to the difference in the initial fat content of the FFM and the SM with values of 3.45 and 0.14, respectively, and thus the FFCCD had higher values than the SMCCD. In most cases the initial fat content of milk used in cheesemaking often reflects that in the cheese (Fox *et al*. 2004b). The fat content showed a tendency to decrease with an increase in the % fruit added. This might be attributed to the sampling pattern where, with an increase in the % fruit added, the samples contained more fruit pulp, thus, the added fruit replaces some of the fat.

According to Fox *et al*. (2004b), the % fat-in-dry-matter (FIDM) in cheese is reported to be of more importance in cheesemaking than the % fat. A trend was observed whereby, the effect of the fruit content decreased % values of the fat content and the FIDM linking it, with an increase in the % fruit added The same justification also applies where the added fruit replaces some of the fat but, the FFCCD still maintains higher values than the SMCCD. Current % FIDM values obtained in this study maybe compared to those stated in the regulation published in the South African Government Gazette (1989). In this study, the % FIDM values were between 28.06 and 44.77% for the FFCCD and 0.55 to 0.60% for the SMCCD and these values fall within the range as stipulated in the Regulation with 45 and 60 % for the FFCCD and 0 to 10% for the SMCCD.

The fat effect on the overall protein content of the two cottage cheese dessert types resulted in the SMCCD having slightly higher values than those of the FFCCD. This could be attributed to the SMCCD having more solids-not-fat (SNF) components than the FFCCD. On the other hand, it is clear that the protein/fat components which form a major fraction of the total solids are linked where the higher percentage of the one component results in lower percentage of the other. The higher protein content and the lower fat content of the SMCCD contributed to its crumbly and firm texture (Paz *et al*. 1998). However, on the contrary, the FFCCD had a smooth texture. Another significant effect on the protein content was that of the fat x fruit interaction where the protein content showed a slight decrease with an increase in the concentration of the added fruit pulp in the two cottage cheese dessert types (0 % > 10 % > 20 % > 30 %). This could be due to the fact that some of the samples contained more of the fruit than the cottage cheese.

The added fruit pulp affected the end ash content values. A trend was observed where, the ash content of the FFCCD and SMCCD increased with an increase in the % fruit added thus 30 > 20 > 10 >control treatments. Ash content values for the FFCCD increased from 1.12 to 1.36 and 1.13 to 1.50 % for the SMCCD. The participatory effect of the added fruit pulp on the ash content of the experimental cottage cheese samples resulted in an average ash value of approximately 1 % and this does not differ from the literature values of 0.7-0.95% (Winwood, 1983; Kosikowski & Mistry, 1999a; Smit *et al*. 1998b).

The increased total solids, as affected by the fat, is quite clear for the two cottage cheese types and this is attributed to the high fat content of the FFCCD as compared to that of the SMCCD (Fox *et* al. 2004b). The same applies for the effect of the fruit added where the total solids content increased with an increase in the % fruit added (0 % > 10 % > 20 % > 30 %) for all the treatments. On the contrary, the same effects and trends were recorded for the moisture content as affected by the fat and the fruit content. The FFCCD had a higher fat content,

thus less moisture content value of 74.61 % and the opposite occured for the SMCCD with a value of 78.76 %. With the fruit effect, the moisture content decreased with an increase in the % fruit added, which augments an increased total solid content from 79.28 to 74.00 %. The total solids of the FFCCD (25.39 %) and the SMCCD (21.24 %) compared well with the 27 % total solids (FFCC) and 20 % total solids (SMCC) standards promulgated in the South African Government Gazette (1989), for cottage cheese with added ingredients. Similar values were obtained in research studies by Koth & Richter (1989), Scott (1998), and Smit *et* al. (1998b).

According to Fox *et al*. (2004b) there is a correlation between the % moisture in fat-free substances (MIFF's) and the % moisture. In the current study, the FFCCD had higher % MIFFS as compared to that of the SMCCD. The total moisture content in cheese often decreases with an increase in the fat content. Therefore, the % MIFFS component is regarded as being more important than the % total moisture. Similar to the moisture content, the % MIFFS decreased with an increase in the pulp concentration and was higher in the control treatment (83.76 > 81.49 > 79.03 > 77.12) for all the treatments. The % MIFFS of the FFCCD and SMCCD in the current study correlate well with literature values of 60-70 % (FFCC) and approximately 80 % for SMCC (Galloway, 1995)

The significant effect of the fruit on the salt content had a tendency to decrease the salt content as the % fruit increased. Due to compositional inbalances in the samples, more of the fruit pulp than the curd was contained. The determined mean salt content value in the current study was approximately 0.1 % as compared with the initial 0.2 % salt, added to the cheese. According to Fox *et al*. (2004b), fluctuations in the % salt are due to the rate of salt incorporation in the cheese curd, especially for dry salted cheeses. In this study it was observed that the % salt-in-water (SIW) was not affected by the fat, the fruit, as well as the fat x fruit interaction.

The calculated % total carbohydrates (TC) values were found to be higher for the SMCCD (11.75 %) than for the SMCCD (7.70 %). This effect is attributed to the lower amount of fat in the former, which resulted in a higher SNF component as compared that of the SMCCD as this can be confirmed when using the equation: % TC =100 - % (moisture + protein + fat + ash) (James, 1995). The FFCCD had higher energy values than the SMCCD, mainly because of its higher fat content. According to James (1995), fat has a high Attwater's general conversion factor (37), compared to that of protein (17) and the total carbohydrates (17) as seen from the equation: kJ= (% protein x17) + (% fat x 37) + (%CHO x17). The effect of the % fruit added with its sugar content contributed to the increased energy values (0 % > 10 % > 20 % > 30 %) in both cottage cheese types by affecting the total carbohydrate content. However, it still remains that the FFCCD had higher values than the SMCCD. Average values increased from 432.8 to 492.5 kJ for the FFCCD.

With the day effect, the pH had a tendency to increase slightly from d1 to d21 (4.37 > 4.48 > 4.59 > 4.76). According to Scott (1998), an increase in pH in the first week (7 day old cheese) is often due to the presence of high concentrations of metabolites formed with the degradation of the milk components (proteins, carbohydrates and lipids). Some of these metabolites are of an alkaline nature and contribute to an increase in pH. In hard types of cheese, this effect has a positive role since it results in the softening of the cheese body (Varnam & Sutherland, 1994).

There was a significant effect on the pH by the % fruit added. A slight decrease in the pH was observed with an increase in the pulp concentration in all the treatments (30 % < 20 % < 10 % < 0 %). In studies of the same nature, Campbell (1989) reported that the acidity of the added fruit pulp played a role in adjusting the final pH of the cheese. Differences noted in the pH values of the experimental cheese, and that of studies conducted by Campbell (1989) were probably because of the differences in the composition of the fruit pulps used and

the manner in which they were added. In studies conducted by Campbell (1989), fruit pulps were mixed thoroughly with the cheese, some placed at the bottom of the cup and in other samples on the surface of the cheese. This might have resulted in the cottage cheese dessert samples not having a uniform consistency. According to Shaw (1986), literature values show that the pH of cottage cheese is between 4.3 and 5.0. These values do not differ much from those of the current experimental cheese with average pH values of 4.54 for the FFCCD and 4.57 for the SMCCD, respectively. The day-to-day effect resulted in increased pH values.

The effect of the fat, fruit and day on the mean titratable acidity (TA) values were observed. The SMCCD had higher TA values than the FFCCD and this could be attributed to the lower fat content values, as well as higher pH values. With the significant fruit effect, the mean TA values decreased with an increase in the % fruit added from 0.60 >0.55 >0.51 to 0.47 and, on the contary, these values increased from day-to-day from 0.50 (d1) to 0.56 (d21). According to Scott (1998) and Tamime & Robinson (1999), a continuous increase in the titratable acidity from day-to-day denotes the continuous acid production resulting from microbial activity. A decrease in acidity values was noted with an increase in the pulp concentration and this could be attributed to the total carbohydrates in the pulp. This effect was also shown in studies conducted by Campbell (1989). It was reported that, with the addition of the fruit pulp, the overall acidity of cottage cheese decreased and this enhanced its keeping quality. The shelf life of cottage cheese increased by 7 days, above the expected shelf life of 21 days. In the current study after day 21 some yeasts and moulds started to grow on the surface, accompanied by signs of syneresis.

During storage, the significant effects of the fat, day as well as the day x fat interaction, were recorded on the total colony count (TCC). With the fat effect, the SMCCD had higher colony counts than the FFCCD. The increased colony counts in the SMCCD could be a result of the multiple milk handlings, during

processing; namely, the fresh full-fat milk was heated, separated mechanically and at a later stage pasteurised unlike the full-fat milk which was pasteurised once off. With the overall day effect, as well as the day x fat interaction, the TCC increased from day 1 to day 21 and the same trend was observed for the two dessert types across all treatments with the SMCCD, showing higher values favourable growth conditions . However, it is clear that high protein and moisture content create these favourable conditions. The high protein content which is measured as the total soluble protein, tends to increase during ripening and this correlates with the less fat content of the SMCCD, which denotes a higher moisture content, a factor which also favours rapidly growing microbes (Varnam and Sutherland, 1994). Under normal circumstances, starter cultures reach their maximum numbers at the end of the cheese manufacturing phase. These numbers will then decline at a rate that will depend on the type of strain used (Fox and McSweeny, 1998).

Sensory evaluation results revealed that the choice and acceptance of FFCCD as well as the SMCCD was based on the effect of the fat, the fruit and the fat x fruit interaction. The significant effect of the fat resulted in higher rating scores for the FFCCD; on average (6.86) as compared to 5.3 of the SMCCD. This could be attributed to the higher fat content in the dessert which in turn resulted in the smoothness in the texture of the FFCCD, as compared to the crumbly, sticky texture and dryness of the SMCCD.

The fruit content, as well as the fat x fruit interaction effects had a tendency to increase with an increase the rating scores with the % fruit added, for example, where 0 % < 10 % < 20 % < 30 % treatment for the two dessert types. The fruit effect increased the overall rating score from 5.59 to 7.31 for the FFCCD and from 4.26 to 6.82 for the SMCCD. These higher scores contributed to the preference of the FFCCD due to the high fat content which was linked with the sweetness of the product and thus the creaminess .

In similar studies conducted by Campbell (1989), sensory attributes of flavoured cottage cheese had more focus on the overall flavour of the product and less was given to the fat content. However, it still showed that the addition of the fruit pulps enhanced the flavour of the cottage cheese and in some instances the shelf life, as well as the eating qualities, which were extended for about two weeks. This could be due to the added fruit pulps that had a tendency to mask off-flavours which could be a result of psychrotrophic microorganisms. Desserts which did not have any added fruit pups showed lack of freshness. In this study comments by the consumer panel indicated that samples with the added fruit pulps tasted like yoghurt, the control samples were disliked and were compared to a fresh cheese with an acidic, sticky and bland taste; the 20 % fruit added treatments for the two dessert types was moderately liked but the 30 % samples were all comperatively liked as these were more sweet.

The distribution of hedonic score-rating showed that the 10 % FFCCD had the highest score, followed by the 20 % and the 30 % FFCCD which compared well with its counterpart, viz, the 30 % SMCCD treatment.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

A novel cottage cheese product, relatively unknown to South African consumers, was developed in this study. Apart from the scientific results, the focus of the study was also developmental aspects of food production and processing, taking into consideration rural and peri-urban areas in South Africa. Milk obtained from such farming activities is mostly for household consumption with minimal processing activities. Milk in these areas is usually consumed fresh or as fermented milk. This study addressed the issue of product development through value adding and developing an alternative product to Amasi/Maas/Yoghurt which is nutritious, tasty, high in protein, safe and cost-effectivene.

Two types of cottage cheese dairy desserts, full-fat cottage cheese dessert (FFCCD) and skim milk cottage cheese dessert (SMCCD) were produced on a small scale, from cow's milk and a comparison was made between the two dessert types regarding the composition, physicochemical, microbial and sensory properties.

The following conclusions are made:

- The separation of the full-fat milk to acquire skim milk lead to a decrease in the total solids of the skim milk, and consequently, to its higher protein content.
- The overall fat content had an effect on the % fat-in-dry matter (FIDM), protein, ash, total solids, moisture, % moisture in fat-free substances (MIFF's), % total carbohydrates (TC) and energy values.
- The fat content played a major role in distinguishing the two desserts types.
- The pH and % titratable acidity (TA) decreased with an increase in the % fruit pulp added due to the higher pH of the fruit pulp
- The pH and % TA also increased due to the production of lactic acid.
- It can also be concluded that the fat effect on the % TA and the total colony count (TCC) is attributed to the high protein content of the SMCCD as compared to that of the FFCCD which resulted in high concentration of

soluble proteins, more moisture and thus favourable conditions for microbial growth. Consequently the same was applicable for the day x fat interaction effect on the TCC as was discussed in Chapter 5. Once again it is noted that the fat content played a major role in this regard.

- Sensory evaluation showed that there is a definite potential for both cottage cheese desserts as new products in the market place, as they compare favourably with fruit blended yoghurts on the market.
- The addition of fruit pulp increased the eating qualities of the cottage cheese desserts. It also increased their shelf life by 7 days, from day 14 to day 21 by decreasing the TA, increased the total solids, total carbohydrates, as well as the energy values.
- The fruit pulp in the cottage cheese desserts affected the overall physico-chemical properties, the shelf life, as well as the sensory attributes of the cottage cheese desserts.
- The proposed manufacturing methods may be adapted for small scale farmers who produce milk on a daily basis to manufacture such cottage cheese desserts, as an alternative to yoghurt and Maas however, proper skills transfer have to be put in place.

Further investigations are necessary to:

- determine the nutrient composition;
- conduct a quantitative descriptive sensory analysis
- determine the shelf life under specific conditions, and
- explore product marketing strategies

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