METHODS TO CONTROL THE MATURATION OF SOFT MOULD RIPENED CHEESE

A thesis submitted in partial fulfilment of the requirements of a Master of Technology (in Food Technology), at Massey University

Shannon Swan
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A special thanks to the *Fab Five* for being my sanity check; to *the Farmer* for being my rock; and to my *Co-Pilots* for above all teaching me to...persevere!

Summary

Soft mould ripened cheeses such as Camembert, typically have a short shelf life in comparison to other cheese varieties, therefore restricting the opportunity to exploit new and developing markets. Preliminary trials were carried out to investigate the freezing point of Camembert cheese and the rate of freezing and thawing that could be achieved using the facilities at Massey University; Albany. Using the results from these trials, a freezing/ thawing protocol and an experimental plan was developed to increase the shelf life by altering the standard storage and maturation profiles of Camembert cheese.

Firstly the effect of three storage temperatures and time (for up to four weeks) on the maturation at +4°C (for eight weeks) of Camembert cheese was investigated. Maturation indicators included: extent of moisture loss of wrapped cheese samples; change in pH of the inside and outside portion of the cheese; change in the release of proteolytic products; change in the viable yeast and mould cells present on the surface of the cheese; and change in texture (uniaxial compression and puncture testing) following storage and throughout maturation. From these results it was found that storing the cheese samples below the freezing point (between -3 and -3.5±0.1°C) had a detrimental effect on the maturation of the cheese. The freezing process and time killed the cheese microflora, therefore inhibiting the release of enzymes which promoted the biochemical reactions within the cheese. As a result the cheese did not follow the same maturation trend as the control sample that was matured at only +4°C for eight weeks. Cheese that was stored at below zero, but above the actual freezing point followed the same maturation trend as the control sample following storage for up to four weeks, therefore showing the most potential in controlling the maturation of the Camembert cheese.

The effect of storage at -2°C on Camembert cheese was then investigated, both throughout the storage of the cheese (for up to six weeks) followed by maturation at +4°C for eight weeks. Maturation indicators included: change in pH of the inside and outside portion of the cheese; change in the moisture content of the cheese; change in the release of proteolytic products; change in texture (uniaxial compression and puncture testing); and Quantitative Descriptive Analysis using a panel of nine

screened and trained panellists. Statistical analysis showed that at the 99% level of confidence, the storage temperature (and time) had no significant effect on the ripening of the cheese throughout maturation at +4°C of the cheese for all maturation indicators. Therefore, storing Camembert cheese at -2°C can be used to control the maturation of Camembert cheese, allowing for longer distribution chain delivery times.

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Glossary

Below is a glossary of terms used throughout various stages of this Masters report:

Term	Definition
Case	Preliminary trials: A cardboard box (70 x 300 x 200mm; HWD) containing 12 units of 210g Puhoi Valley Ltd. Camembert cheese; six units on the bottom layer, and six units on the top layer
Controlled maturation	The effect of manipulating the storage time and temperature to optimise the potential shelf-life of Camembert cheese
Control sample	Stage ONE trials: Camembert cheese samples were held at +4°C maturation for up to seven weeks Stage TWO trials: Camembert cheese samples held at -2°C for up to 14 weeks
Maturation temperature	The temperature Camembert cheese samples were held at +4°C, as recommended in Puhoi Valley Cheese product specification
Maturation time	The time (weeks) that the Camembert cheese samples were held at +4°C
Maturation properties	The rheological/ textural, compositional, biochemical, sensory and microbiological changes that are characteristic to Camembert cheese
Reference sample	Stage TWO QDA trials: Camembert cheese samples were picked up fresh from Puhoi Valley Cheese Ltd. prior to sensory evaluation
Storage temperature	The temperature that Camembert cheese samples were held at prior to maturation For example: Stage ONE Trials (+1°C, -2°C and -10°C), Stage TWO Trials (-2°C)
Storage time	The time (weeks) that the Camembert cheese samples were held at each respective storage temperature treatment
Total holding time	The sum amount of time (weeks) that the Camembert cheese samples were held during storage and maturation
Week	The unit of time used in this study. One week = seven days

1.0 Introduction

The development of cheese (an estimated 8000 years ago) was firstly intended as a milk preservation method to retain the valuable micro- and macro-nutrients in milk. Cheese manufacture has now developed into an industry where approximately 14 x 10^6 tonnes is manufactured each year, representing 30% of the total world sales of dairy products (Fox and McSweeney, 1996; Farkye, 2004). New Zealand's dairy industry is estimated to make up only 2% of the world's total dairy production, but accounts for 35% of international trade in dairy products. According to Statistics NZ (2010) dairy exports inject an estimate $8.8 billion (NZD) to the economy each year, exporting approximately 285,000 MT of cheese.

Accelerated ripening methods have been the primary focus of the world wide dairy industry, as the maturation of cheese is responsible for a significant portion of the total production cost (Kolakowski *et al.,* 1998), however being able to slow and control the maturation in order to improve the shelf life of some cheeses is gaining significant commercial interest because of the potential to open and exploit new market opportunities, allowing for longer distribution chains and exportation. According to Desorby and Hardy (1994) and Anon (1998), extending the shelf life of cheese requires the simultaneous investigation into both cheese and storage technologies. Investigations into the effects of various temperature and time regimes can have a positive impact on the quality of cheeses and make them suitable for export (Marshall and Waugh, 1978).

Puhoi Valley Cheese is a subsidiary of Goodman Fielder New Zealand Limited, and manufactures a range of specialty cheeses including Camembert and Brie. These cheeses are characterised by white mould skin that establishes on the surface of the cheese curd within ten days of manufacture, prior to packaging. At present, the company is distributing cheeses throughout New Zealand. From the date of packing the cheeses have a seven week shelf life; therefore methods to extend product shelf life without affecting product quality would increase the company's distribution capabilities, including the potential for export and entry into international markets. The objectives of the current work were to:

1. Carry out an extensive review of literature to investigate various methods to control the maturation rate of Camembert cheese;
2. Determine the freezing and thawing profile of Camembert cheese;
3. Examine the effect of various holding temperatures and times on the maturation and organoleptic properties; and consumer acceptability of Camembert cheese;
4. Make recommendations regarding the most effective temperature/ time regime for controlling the maturation of Camembert cheese.

2.0 Literature Review

Figure 2.1 shows the structure of this literature review.

Subjects where quantitative methods were investigated and detailed

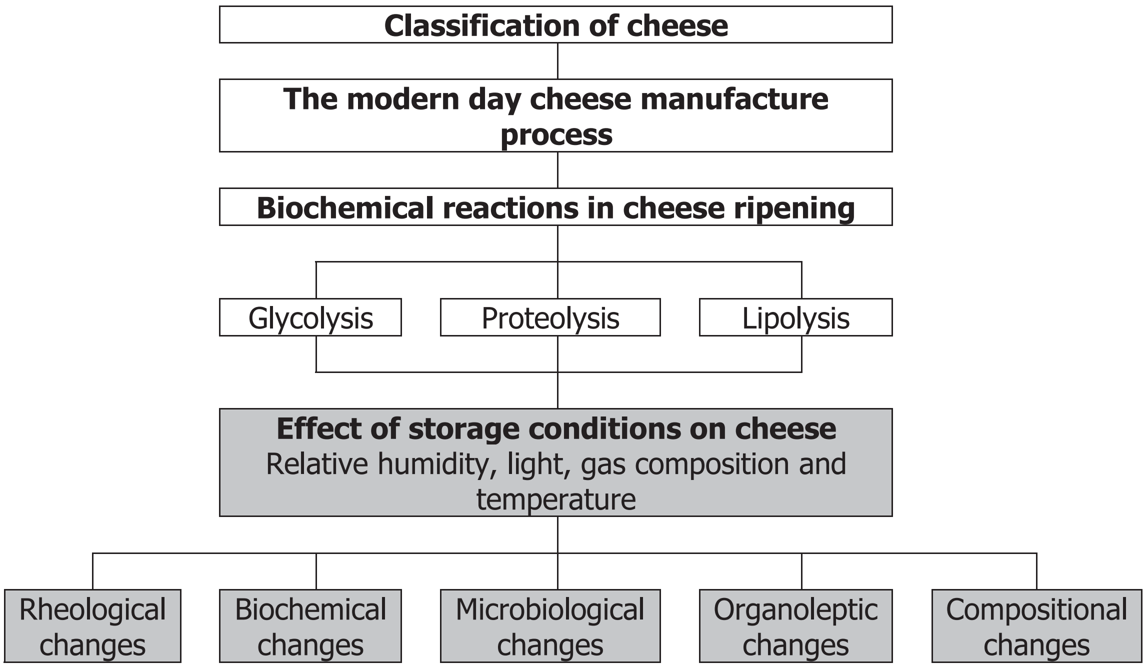
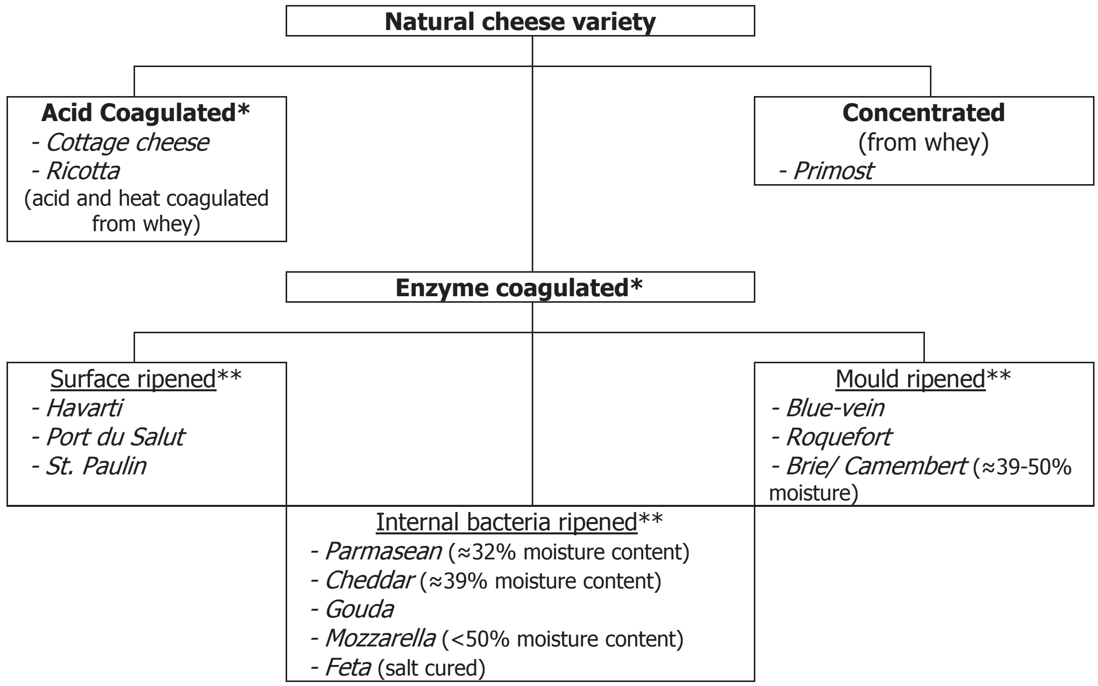


Figure 2.1: Structure of this literature review

2.1 Classification of cheese

Cheese is a unique ecosystem which contains a range of indigenous and exogenous microflora; which simultaneously helps to characterise the cheese variety (Fox and McSweeney, 1996; Cogan *et al.,* 1997). Milk is made up of approximately 94% water, and in the manufacture of cheese the water is expelled from the matrix by coagulating the milk proteins enzymatically, isoelectrically; or by a combination of heat and acid (Fox, 1989), see **Figure 2.2**. Depending on the cheese variety, the casein and fat content of milk is concentrated approximately 6 to 12-fold (Fox, 1989; Fox *et al.,* 1990; Lucey and Fox, 1993; Boutrou *et al.,* 1999; Collins *et al.,* 2003).



Combined adaptation from Gunasekaran and Ak (2003) and Farkye (2004)

Figure 2.2: Classification of natural cheese varieties according to the coagulation agent (*) and maturation mechanism (**)

Camembert is classed as a semi-soft cheese which is surface ripened using mould species, these characterise the organoleptic properties of the cheese throughout maturation (El Soda and Pandian, 1991; Nootigedagt and Hartog, 1988; Antoniou *et al.,* 2000). This cheese has a high moisture content which reduces the shelf life to approximately seven to eight weeks (Nooitgedagt and Hartog., 1988; Fox *et al.,* 2000).

Cheese composition includes the moisture content, protein, fat, sodium chloride, milk salts and pH (Lucey *et al.,* 2003). **Table 2.1** outlines the typical composition of Camembert cheese.

Table 2.1: Typical composition (% by weight) of Camembert cheese

Component	**Composition** (% by weight)
Total Fat	23.0
Total Solids	47.5
Protein	18.5
Salt	2.5
Ash	3.8
Water Activity	0.97
pH (at time of retailing)	6.9

Adapted from Fox *et al.* (2000)

2.2 The modern day cheese manufacture process

Typically the yield (fat and milk proteins) of the cheese-making process is between 9 and 15% and depending on the cheese variety. Composition of the micronutrients of milk, heat treatment and processing can also influence the cheese yields (Farkye, 2004).

The manufacture of most cheese varieties involves combining four main ingredients (milk, rennet, microorganisms and salt) which are brought together through a range of steps. These include milk standardisation, pasteurisation, drainage, curd manipulation, and maturation conditions (Beresford *et al.,* 2001; Lucey *et al.,* 2003; Coker *et al.,* 2005). **Figure 2.3** outlines the key steps involved in the manufacture of mould ripened cheeses.

Milk
Pre-treatment and standardisation
Pasteurisation

Cheese milk
Addition of:
Microflora (used for acidification)
$CaCl_2$ (optional)
Coagulation (rennet or acid [produced *in situ* or pre-formed] or heat/acid)

Coagulum (gel)
Cut coagulum
Stir
Heat
Acidification (rennet-coagulated cheeses)
Separation of curds from whey

Curds
Acidification
Salting (some varieties)
Molding
Pressing (some varieties)

Fresh cheese
Salting (most varieties)
Ripening (most rennet-coagulated cheeses)

Mature cheese

Adapted from Fox *et al.* (2000)

Figure 2.3: Key steps involved in the manufacture of mould ripened cheese

2.2.1 Cheese milk preparation

Preparation of the cheese milk includes two key steps:

1. Standardisation;
2. Pasteurisation.

2.2.1.1 Standardisation

The purpose of standardisation is to ensure a uniform total solids content (%) and quality of the final product. Traditional standardisation of milk involves achieving a specific total fat, or milk protein-to-fat ratio by cream addition, or the addition of skim milk (Kindstedt, 1993; Lucey *et al.,* 2003; Farkye, 2004). Newer technologies such as ultra filtration (UF) are becoming increasingly popular in cheese standardisation whereby membranes (10^{-2} – 10^{-1}µm) are used to concentrate up the fat, protein and lactose. According to Farkye (2004), UF is becoming increasingly popular in the manufacture of high moisture cheeses, such as Camembert. Cheeses which have been manufactured using this technology have been shown to achieve higher yields than cheeses which are made using traditional methods.

2.2.1.2 Pasteurisation

The standard temperature-time regime for pasteurisation is typically carried out at 72^{o}C for 15 seconds (Farkye, 2004). The purpose of pasteurisation is to eliminate any pathogenic bacteria present in the milk. Research has shown that pasteurisation can also contribute to the reduction of indigenous microflora and enzymatic activity; and the denaturation of some serum proteins (Grappin and Beuvier, 1997; Urbach, 1997).

2.2.2 Conversion of milk to cheese

The conversion of milk to cheese takes place after the cheese milk has been pumped into a vat. These steps are vital in the manufacture of cheese and include:

1. Addition of microflora, calcium and rennet);
2. Milk coagulation ;
3. Cutting the coagulum;
4. Cooking and draining the whey;
5. Moulding and pressing the curd;
6. Salting.

2.2.2.1 Addition of cheese microflora

Micro-organisms are an essential component of all natural cheeses and play an important role during both cheese manufacture and ripening (Beresford *et al.,* 2001). The microflora of a cheese is made up of aerobic bacteria, yeasts and moulds. These microflora are added in varying concentrations, depending on the cheese variety. According to Beresford *et al.* (2001) cheese micro-organisms can be divided into two main groups: starter cultures, which are responsible for acid development during cheese production; and secondary flora, composed of mixtures of bacteria, yeasts and moulds. The secondary micro-organisms do not contribute to acid production, but metabolise the lactic acid via biochemical activities (primarily lipolysis and glycolysis) which impacts on the modification of the texture and flavour of Camembert cheese (Lenoir, 1984; Karahadian and Lindsay, 1987; Beresford *et al.,* 2001; Boutrou *et al.,* 2006).

The microflora used in the initial stages of Camembert cheese manufacture (predominantly starter lactic acid producing bacteria) are anaerobic micro-organisms (Fox *et al.,* 2000; Tortora *et al.,* 2004), while the yeasts and moulds are strictly aerobic (O'Shea *et al.,* 1996). Filamentous moulds such as *Penicillium camemberti* and *Penicillium roqueforti* are responsible for the distinct appearance of Camembert cheese; and are also involved in important biochemical reactions which contribute to the characteristic textural and organoleptic properties of the product (Leclercq-Perlat *et al*., 1999).

2.2.2.2 Addition of calcium

The natural concentration of calcium in milk is approximately 117 mg/ 100g and phosphate is approximately 203mg/ 100g. Collectively calcium phosphate acts as the "glue" between individual caseins forming the casein micelle (Lucey and Fox, 1993). The relative concentrations of these two minerals in the milk can be modified by the process of ultra-filtration (Le Graet *et al.,* 1983).

The addition of calcium chloride (to 0.02g/L) to the milk reduces the pH and aids in achieving a constant gel firmness and coagulation time (Lucey and Fox, 1993; Lucey, 1996; Fox *et al.,* 2000).

2.2.2.3 Addition of rennet

Rennet is added to the cheese milk to initiate the primary phase of milk coagulation by the initial hydrolysis of milk proteins (Fox *et al.,* 2000). The activities of the proteinases within the rennet have an important influence on the final product by reducing the cheese yield. If the cheese milk sets too quickly following the addition of the rennet, or if an incorrect dosage is added this can result in excessive hydrolysis or incorrect specifity of milk proteins; causing in flavour (particularly bitterness) or textural defects.

Traditionally rennet is derived from animals, as a result of consumer demand; rennets from other sources (plant and microbiologically derived rennet's) are increasingly becoming commercially available.

2.2.2.4 Milk Coagulation

Native casein micelles in fresh milk consist of casein proteins and calcium phosphate, and have a spherical radius of approximately 100nm. The dispersion of casein micelles in milk is very stable, primarily owing to κ-casein (present mainly on the surface of the micelle structure) where the C-terminal, consisting of approximately 14-carboxylic groups extends into the continuous phase of the milk, made up of water, salt, lactose and serum proteins (de Kruif, 1999; Fox *et al.,* 2000). The coagulation of milk proteins in cheese making occurs in two phases: primary (enzymatic coagulation) and secondary (non enzymatic coagulation) and the methods of coagulation include: denaturation of the milk proteins using rennets or other coagulants, acidification by the addition of starter cultures, or through the addition of acids and heat; or combinations of these methods (Lucey and Fox, 1993; Lucey *et al.,* 2003).

Milk coagulation is initiated by the addition of starter LAB which work to metabolise the natural milk sugars (predominantly lactose), thus reducing the initial pH of the milk (Adda *et al.,* 1982; Trieu-Cuot and Gripon, 1982; Fox *et al.,* 1990; Crow *et al.,* 1993; Crow *et al.,* 1995; Fleet, 1999; Fox *et al.,* 2000; Guizani *et al.,* 2002; Coker *et al.,* 2005). This change in pH solubilises the calcium phosphate between the individual casein units exposing of the four different casein proteins (κ-casein, β-casein, α_{s1}-casein and α_{s2}-casein), and allowing the initiation of enzymatic activity from the rennet (Green, 1977; Kindstedt, 1993; Fox and McSweeney, 1996; Cogan *et al.,* 1997; de Kruif, 1999; Beresford *et al.,* 2001). The gelation of the curd proceeds fasters as a result of a reduction in the pH (at pH values 4.6 to 6.8; optimum 5.8) and therefore is most active immediately following glycolysis (Green, 1977; Lucey *et al.,* 2003).

Only κ-casein is hydrolysed during the primary phase of rennet action where the action of chymosin cleaves the casein at the glyco-macro-peptide (GMP). This yields two peptides altering the colloidal stability of the micelle therefore making the protein more susceptible to aggregation (Lucey and Fox, 1993; Fox and McSweeney, 1996; Broome and Limsowtin, 1998; Fox, 2003; Farkye, 2004). Flocculation occurs when the cleavage of the GMP bond is 80 to 90% complete (Fox, 1989; de Kruif, 1999). This reduces the stability of the casein micelle to such an extent that when they collide they remain in contact forming chains and eventually building a three-dimensional matrix (gel). This gelation process is often referred to as the secondary stage of coagulation (Fox *et al.,* 2000).

The formation of a coagulum (gel); where milk proteins and fat (excluding the whey fraction), lactose and minerals are entrapped within the curd matrix (Fox *et al.,* 1990; Lucey and Fox, 1993; Broome and Limsowtin, 1998; Boutrou *et al.,* 2002; Farkye, 2004). The extent to which this occurs is dependent on the temperature, pH (maximum pH = 6.0 to 6.2), degree of agitation, protein concentration and Ca^{2+} concentration; all of which can be manipulated through the cheese manufacturing process (Grandison *et al.,* 1984; Fox *et al.,* 1990; Lucey and Fox, 1993; Lucey, 1996; Lucey *et al.,* 2003).

The time that it takes for the milk to coagulate and form a gel is known as the rennet coagulation time, which has been correlated to the concentration of fat, casein, fat-casein ratio, lactose, and minerals: sodium and potassium. A positive correlation has been observed between coagulation time, fat and potassium concentrations (coagulation time increased with increasing concentrations). A negative relationship has been observed between coagulation time and casein, fat-casein ratio, lactose and sodium concentrations (coagulation time decreases with increasing concentrations) (Grandison *et al.*, 1984). This trend has been confirmed by Kefford *et al.* (1995) and Lucey (1996) who showed that milk that was produced throughout late autumn/ winter (low fat, protein and lactose concentrations) had a longer coagulation time and a low cheese firmness resulting in an inferior quality cheese with an elevated moisture content and impaired functionality. Studies have shown that if the curd is cut when it is very soft, the moisture content of the cheese will be low, whereas if the curd is left for longer prior to cutting, the moisture content of the cheese will be higher, which is a reflection of the extent of bonding between casein micelles (Lucey and Fox, 1993; Boutrou *et al.*, 2002; Lucey *et al.,* 2003).

2.2.2.5 Cutting the coagulum

Cutting the coagulum is an essential process step in the manufacture of cheese, and in modern cheese making facilities this is an automated process, where traditionally this was carried out manually. Cutting takes place after the coagulum is set (typically 30 minutes) and the process is designed to gently break the curd into 3-15mm “lumps” depending on the type of cheese. The larger the “lumps” the, higher the moisture content in the resulting cheese (Fox *et al.,* 2000; Farkye, 2004).

2.2.2.6 Cooking and draining the whey

Cooking takes place following the cutting of the curd and is important in regulating the growth of acid producing bacteria and therefore controls the conversion of lactose to lactic acid by the starter cultures (Farkye, 2004). The heating process also promotes the contraction of the curd, expelling the whey and influencing the final moisture content of the cheese. Following heating the whey is drained from the vat at a consistent volume (35-50%) depending on the cheese variety (Kindstedt, 1993; Fox *et al.,* 2000).

2.2.2.7 Moulding and Pressing

Moulding is the process by which the curd is transferred into moulds and then pressed. Pressing is designed to assist in shaping, forms the texture/ density of the cheese and also aids in expelling the final whey from the curd. The cheese is typically pressed for 15-20 hours, with occasional turning before it is brine salt treated (Fox *et al.,* 2000).

2.2.2.8 Salting

The addition of salt to the cheese formulation, and salt brining contribute to the flavour, regulation of moisture retention and microbiological activity (Macedo *et al.,* 1997; Farkye, 2004; Kilic and Isin, 2004). Through brining the cheese units are soaked in a concentrated salt solution which absorbs some of the brine resulting in an inconsistent salt concentration throughout a cross-section of the cheese. Differences in salt concentration between the rind and the centre of the wheel of 0.3% have been noted in Camembert cheese, however this has been found to standardise throughout ripening (Noel and Lefier, 1991; Engel *et al.,* 2001b).

2.2.3 Ripening and maturation

The conditions which are set for the ripening process allow the principle microbiological and biochemical ripening reactions to continue which aid in the development of the characteristic properties of the cheese. In the manufacture of mould ripened cheeses, the temperature and humidity are set to permit the growth of the surface microflora, while reducing the evaporation of moisture from the cheese surface (Fox *et al.,* 2000).

2.2.4 Summary of the cheese manufacture process

Overall it was found that:

1. The cheese microflora have a primary role in defining the essential characteristic properties of natural cheeses during both cheese manufacture and ripening;
2. The optimisation of ripening and maturation conditions are essential in promoting the necessary microflora growth and biochemical reaction in natural cheeses.

2.3 Biochemical reactions in cheese ripening

Three main chemical and biochemical processes are involved in the cheese maturation process (Smit *et al.*, 2002), see **Figure 2.4**.

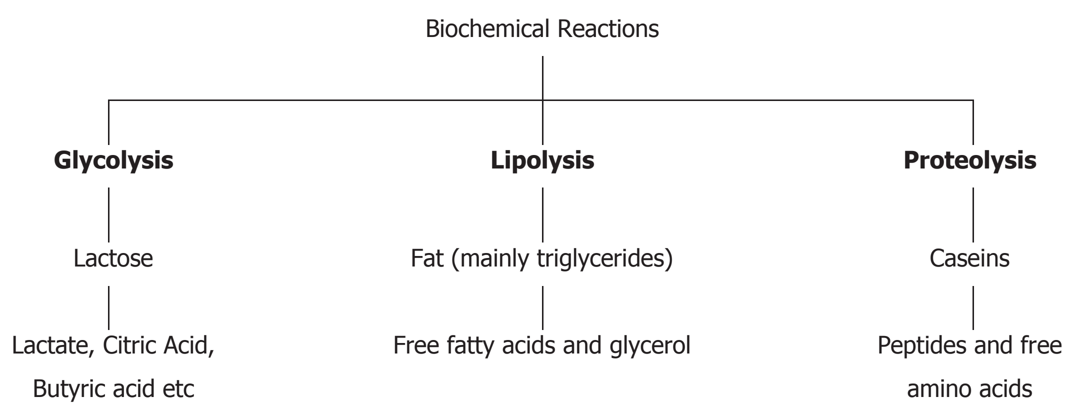


Figure 2.4: Summary of the evolution of compounds which give rise to the flavour and aroma in cheese

Cheese maturation during storage is affected by the interplay of several factors such as:

- Proteolytic and lipolytic enzymes (which can originate from the milk, the rennet or starter micro-organisms);
- Storage temperature and time;
- Salting and pH of the curd;
- Humidity.

(Richardson and Creamer, 1973; Visser, 1976; Lawrence *et al.,* 1987; Jin and Park, 1995).

2.3.1 Glycolysis

Glycolysis is the first major biochemical reaction that occurs in the manufacture of cheese and is responsible for the conversion of lactose to lactate by the starter bacteria. This causes a drop in pH subsequently the growth of microflora which characterise Camembert cheese (Adda *et al.,* 1982; Fox and Wallace, 1997; Smit *et al.,* 2002; McSweeney, 2004). The activation time of Lactic Acid Bacteria (LAB) for the initiation of glycolysis ranges from one to four hours from when the LAB are added to the cheese milk (Fleet, 1999). Ninety-eight percent of the lactose which is present in raw milk is removed in the whey, leaving approximately 1.0 to 1.5% lactic acid in the young cheese curd. This is mainly produced from mesophillic organisms (optimum temperature 30^{o}C) and is metabolised to lactate (Fox *et al.,* 1990; Fox and Wallace, 1997). Between the start of ripening (day zero) and the sixteenth day, the concentration of lactate decreases rapidly starting at the rind, creating a pH gradient between the surface and the centre of the cheese. By the 42nd day of ripening, the concentration of lactate is typically uniform throughout Camembert cheese (Engel *et al*., 2001b).

The starter bacteria contribute to the development of both taste and aroma in Camembert cheese. Starter bacteria ferment lactose, metabolise citric acid and initiate the breakdown of proteins which are widely accepted as being essential for the flavour development in cheese (Adda *et al.,* 1982; Urbach, 1997; Beresford *et al.,* 2001; Williams *et al.,* 2001). However, if the population of starter organisms survive for too long or if the numbers are too large this indicates high potential for the development of bitter or off-flavours, whereas in cheese where low numbers of bacteria are present no flavour develops (Ohren and Tuckey, 1969; Lenoir, 1984; Crow *et al.,* 1993; Beresford *et al.,* 2001).

Lactic acid can be isomerised or converted to acetic, propionic or butyric acid, and pyruvate (an intermediate compound in the conversion of lactose to lactate) and can result in typical yoghurt flavours such as diacetyl, acetoin acetaldehyde, or acetic acid (Fox and McSweeney, 1996; Smit *et al.,* 2002). Kubícková and Grosch (1998) indicate that the pungent and sweaty characteristics in Camembert cheese are mainly caused by acetic acid and butyric acid.

2.3.2 Lipolysis

Lipolysis is an enzymatic reaction by which the fats (mainly triglycerides) in the cheese curd are degraded to free fatty acids and glycerol by endogenous or exogenous lipases (McSweeney, 2004). This reaction is started as a result of the presence of lipolytic enzymes; which can be classified as either esterases or lipases (Adda *et al.,* 1982; Crow *et al.,* 1993; Fox and Wallace, 1997; Urbach, 1997; Smit *et al.,* 2002; Collins *et al.,* 2003).

Lipolysis is a major pathway for flavour generation during cheese ripening where the amount of free fatty acids differs according to the type of cheese (Smit *et al.,* 2002; Collins *et al.,* 2003). Fatty acids released upon lipolysis are the precursors to the production of volatile short chain fatty acids which contribute directly to cheese flavour, especially in mould ripened varieties (containing up to 10% free fatty acids). However these compounds can be considered undesirable in other cheese varieties (Adda *et al.,* 1982; Fox and Wallace, 1997; Urbach, 1997). Common desirable compounds which contribute to the flavour of Camembert cheese include: methyl-ketones, alcohols and lactones (Fox and McSweeney, 1996; Urbach, 1997; Smit *et al.,* 2002; Collins *et al.,* 2003).

Studies have shown that cheeses which have been made with low fat milk do not develop the same flavour or aroma profiles as cheeses made with a higher fat content (Ohren and Tuckey, 1969; Adda *et al.,* 1982). However, it is not clear as to whether this is due to the lack of the precursor fat leading to the:

- Release of free fatty acids;
- Lack of the solvent power of the fat (thus allowing essential flavour compounds to escape);
- Different physical structure of the reduced fat cheese which inhibits certain enzymatic reactions and are essential for the development of flavour compounds (Urbach, 1997).

2.3.3 Proteolysis

Proteolysis is the most complex and perhaps the most important biochemical reaction that occurs during ripening, and it involves the hydrolysis of the caseins (α_{s1}-, α_{s2}-, β- and *para-κ*-casein) to free amino acids by proteinases (Fox and Wallace, 1997; Smit *et al.,* 2002; Sousa and McSweeney, 2001; Verdini and Rubiolo, 2002a; Coker *et al.,* 2005). These proteinases originate from a wide range of sources including animal, microbial or plant derived rennets, indigenous milk enzymes (plasmin), starter and non-starter micro-organisms (LAB, yeasts and moulds). These all work synergistically to break down protein during cheese manufacture and ripening (Gripon *et al.,* 1977; Karahadian and Lindsay, 1987; Fox, 1989; Zamorani *et al.,* 1992; Engels and Visser, 1994; Fox and McSweeney, 1996; Fox and Wallace, 1997; Sousa and McSweeney, 2001; McSweeney, 2004; Coker *et al.,* 2005). The activity of these enzymes in the cheese can be affected by alterations in cheese formulation (protein, water and salt concentration and pH), manufacture and storage conditions (temperature) and ripening duration (Dulley, 1976; Visser, 1976; Green, 1977; Verdini and Rubiolo, 2002b).

Proteolysis plays several key roles in the ripening of cheese including; the increase in pH, decrease in water activity and texture (softening); and flavour development (Adda *et al.,* 1982; Grappin *et al.,* 1985; Fox, 1989; Zamorani *et al.,* 1992; Fox and McSweeney, 1996).

2.4.1 Summary of biochemical reactions in cheese

Overall it was found that:

1. The glycolysis is responsible for initiating lipolysis and proteolysis in Camembert cheese by the drop in pH;
2. Lipolysis influences cheese flavour by the hydrolysis of free fatty acids within the cheese matrix;
3. The breakdown of milk proteins (proteolyis) influences the pH; and characterises the texture and flavour development of Camembert cheese.

2.4 Storage of cheese

During storage, foods can deteriorate through a range of mechanisms which include the enzymatic degradation of fats and proteins resulting in detrimental changes to the characteristics of the product (Labuza *et al.,* 1972). Having the ability to quantify the kinetics of deterioration allows the best basis for the determination and optimisation of storage conditions, such as the relative humidity of the storage chamber, exposure of the product to light, storage temperature, length of storage (Labuza *et al.,* 1972; Richardson and Creamer, 1973; Lawrence *et al.,* 1987; Jin and Park, 1995).

2.4.1 Relative humidity

The relative humidity of the ripening chamber affects the final moisture content of cheeses by influencing the rate of cooling and water evaporation (Dinçer, 2003). It has been shown by Macedo *et al.* (1997) and Picque *et al.* (2006) that the lower relative humidity of the ripening chamber the higher the observed weight loss in Camembert cheese. Therefore, according to Dinçer (2003), throughout long term storage of any food product, it is essential that the relative humidity of the chamber be maintained at as high a level as is practical. The relative humidity is difficult to control at temperatures below $0^{o}C$.

Changes in water loss affect water activity and consequently the growth and activity of the microorganisms involved in ripening (Picque *et al.,* 2006). Roger *et al.* (1998) has shown that at a relative humidity of 92%, the respiration and growth rate of *Penicillium camemberti* is at its lowest, therefore reducing the rate of any biochemical reactions which this microorganism is involved in.

2.4.2 Light

Many deteriorative changes in the nutritional quality of foods are initiated or accelerated by light (Robertson, 1993). Kristoffersen *et al.* (1964) has indicated that natural cheeses are more susceptible to light, and the development of oxidised flavours than processed cheese varieties. However, Robertson (1993) has shown that soft cheeses such as Camembert and Brie only require limited protection against light in comparison to other cheese varieties. The formation of the mould mycelium layer on the surface of these cheeses provides protection against light induced oxidative reactions.

2.4.3 Gas composition

According to Bishop (1990) controlled storage is used to extend the storage life of food products by controlling the precise temperature and gas composition in order to maximise the storage life of a food product. Various types of controlled storage techniques are outlined in **Table 2.2**.

Table 2.2: Various types of controlled storage techniques and their basic principles

Controlled Storage Techniques	Principles
Controlled Atmosphere	A low O_2 or high CO_2 environment is created using natural respiration or artificial techniques, and is then controlled throughout the storage period
Controlled Ventilation	CO_2 is allowed to build up by natural respiration, and is then controlled to a defined level using ventilation systems
Modified Atmosphere	The atmosphere is flushed with the required composition of N_2, O_2, and CO_2 which is maintained throughout the storage life. No correction flushing takes place
Ultra low oxygen storage	Concentrations of oxygen of less than 2% throughout storage

Adapted from Bishop (1990)

The gaseous environment in which cheese is stored can have a significant impact on the kinetics of deteriorative reactions which are associated with the ripening process; most significantly the:

- Surface area to volume ratio (and therefore the exposure of the product to the gaseous environment);
- Influence of the gas make-up on the growth;
- Respiratory activities of micro-organisms involved throughout maturation and the water losses of the product (Labuza *et al.,* 1972; Robertson, 1993; Picque *et al.,* 2006).

According to Walker and Betts (2000) temperature regulation control is essential in obtaining the peak benefits of controlled storage techniques, more specifically vacuum and modified atmosphere packaging.

Carbon dioxide (CO_2) has been reported as a natural antimicrobial agent inhibiting the growth of bacteria and some yeasts and therefore could potentially be used to slow the development of off flavours and extend the shelf life of solid dairy foods by up to five weeks (Anon, 1998; Westall and Filtenborg, 1998).

However a study carried out by Picque *et al.* (2006) showed that when CO_2 (2 to 6%) is injected into the ripening chamber of Camembert type cheeses, the respiratory activity of the product increases, in comparison to trials which were carried out where the CO_2 concentrations were not regulated. These results are supported by results from an earlier study where the respiration rate of *Penicillium* *camemberti* was found to increase with CO_2 partial pressure values ranging from 0.1 to 0.4 Pa (Roger *et al.,* 1998). Picque *et al.* (2006) also found that CO_2 concentrations of more than 2%, had a negative influence on the appearance of the cheese, and proteolysis was faster and more significant.

Oxygen scavenging systems absorb oxygen gas in the packaging layer and prevent the growth of aerobic microorganisms (yeasts and moulds) and biochemical processes (Han, 2000; Walker and Betts, 2000). The respiration rate of surface microflora during Camembert ripening in the presence of varying concentrations of oxygen was measured by Roger *et al.* (1998). From this study, it was shown that the growth of *Penicillium camemberti* increased with increasing concentrations of oxygen, and growth was stunted when the partial pressure of oxygen in the ripening chamber was equal to zero. This is supported by claims made by Labuza and Breene (1989) and Walker and Betts (2000) where it was suggested that moulds do not grow under low oxygen conditions. Other surface microflora, such as yeasts are able to continue to grow in the presence and absence of oxygen (Walker and Betts, 2000).

No studies have specifically investigated the influence of nitrogen on the ripening of soft, mould ripened cheeses, however it has been shown that an ammonia rich atmosphere has a significant effect on the ripening of soft cheeses (Picque *et al,* 2006). Ammonia was shown to increase the pH earlier than usual, reducing the growth of *Penicillium* and therefore reducing the level of proteolysis and the development of off-flavours.

A study conducted by Karahadian and Lindsay (1987) showed that when a unit of brie was exposed to a head space of ammonia hydroxide, at concentrations of up to 0.5%, this product resulted in extensive structural collapse of the cheese sample.

Therefore, these results collectively indicate that the maturation rate of Camembert cheese can be controlled by manipulating the gas composition of the ripening chamber:

1. The respiration rate of the surface microflora of Camembert increases in the presence of increased concentrations of carbon dioxide;

2. The growth of the *Penicillium* species is reduced when the partial pressure of oxygen in the ripening chamber is equal to zero;
3. An ammonia environment decreases the rate of proteolysis in Camembert cheese; however it has also been shown to have negative effect on the texture of the product.

2.4.4 Storage temperature

Modifying the storage temperature is considered to be a preservation method that can be used to regulate the changes which occur during cheese maturation (Robertson, 1993; Picque *et al.,* 2006). More specifically, it can influence the rate of proteolysis, evolution of the cheese microflora, development of texture and the quality of the final product (Aston *et al.,* 1983 a, b; Folkertsma *et al.,* 1996).

Table 2.3 summarises various maturation temperatures for different types of cheese, and the key findings with regard to rheology/ texture, cheese composition, biochemical changes, sensory/ organoleptic attributes and the microflora.

Storage temperature contributes significantly to the production costs of cheese and therefore in an attempt to control the texture and flavour development in certain cheese varieties the temperature of the maturation chamber can be altered accordingly. **Table 2.3** indicates that most of the articles investigated in this literature review focus on the accelerated ripening of hard cheddar type cheeses.

Chilling temperatures are considered those which are close to but above the actual freezing point of fresh foods (usually between -1 to 7°C) and is said to retard moisture loss, slow deteriorative chemical reactions, metabolic activities and the growth of microorganisms (Robertson, 1993).

Table 2.3: Summary of various studies conducted with regard to the influence of ripening temperature on key cheese maturation properties

Author	Cheese type	Control maturation temperature (°C)	Sample storage temperature (°C)	Key findings				
				Rheology / texture	**Composition**	**Biochemical changes**	**Sensory/ organoleptic attributes**	**Microbiological changes**
Yamamoto *et al.* (1970)	Cheddar	10	15	"Poor" texture	Water loss	Increased concentration of water-soluble nitrogen and free amino acids	Increased perceived fermented odour, and the development of a strong tasted	NI
Lück (1977)	Camembert and Brie	-	0 to -10°C	After 2 months the outer part was crumbly, while the centre was creamy	NI	NI	Development of brown discolouration after 5 months storage	Between -3°C and 0°C mould growth still occurs
Marshall and Waugh (1978)	Cheddar	3	7, 9 and 11	NI	No significant difference in the composition between storage temperatures	NI	Increased perception of "slightly stale" or "slightly lipolytic" with increasing temperature	NI
Aston *et al.* (1983b)	Cheddar	8	13 or 20	NI	NI	Increase in the level of proteolytic products (total free amino acids); the extent of which is proportional to the sample temperature	Total flavour and mature flavour scores were lower at 13°C than at 20°C	NI

Author	Cheese type	Control maturation temperature (°C)	Sample storage temperature (°C)	Key findings				
				Rheology / texture	Composition	Biochemical changes	Sensory/ organoleptic attributes	Microbiological changes
Cervantes *et al.* (1983)	Mozzarella	5.6	-15	No consistent or statistically significant effects found in regard to compression attributes following 7 days of storage at -15°C Following freezing and tempering at 5.6°C for 21 days the cheese was significantly softer	Increase in salt concentration	NI	No consistent or statistically significant effects found	NI
Fedrick *et al.* (1983)	Cheddar	8	Variations of 8, 13, and 20°C for up to 32 weeks	NI	NI	Level of proteolysis increased for all treatments	Significantly increased flavour scores for all treatments ($p > 0.10$)	NI
Aston *et al,* (1985)	Cheddar	8	Variations of 8, 13, and 20°C for up to 32 weeks	NI	NI	Level of proteolysis increased for all treatments	Significantly lower preference scores in comparison to the control due to the development of off flavours ($p > 0.05$)	NI
Jarmul *et al.* (1985)	Camembert	-	-27°C	NI	NI	Following thawing lipolysis proceeded faster than proteolysis	NI	NI

Author	Cheese type	Control maturation temperature (°C)	Sample storage temperature (°C)	Key findings				
				Rheology / texture	Composition	Biochemical changes	Sensory/ organoleptic attributes	Microbiological changes
Alonso *et al.* (1987)	Cabrales Cheese	9 to 10	- 40	NI	No significant difference in pH, fat, total solids, ash and NaCl content	Decrease in total nitrogen, soluble nitrogen, non-protein nitrogen, free amino acids ($p < 0.05$) No significant difference in the lipolysis parameters	NI	NI
Oberg *et al.* (1992)	Mozzarella	4.4	- 20 and-70	No significant difference in the "stretch" ($p > 0.05$) Frozen cheese melted less than control ($p < 0.05$)	NI	NI	No significant differences in colour	NI
Crow *et al.* (1993)	Cheddar	-	13, 22 and 30	NI		Increased concentrations of Free Amino Acids, alanine and free branched amino acids		
Jin and Park (1995)	Seven goat cheese varieties including soft cheeses	4	13 and 22		The pH of the cheese stored at 22°C was significantly lower than that at the other two temperatures ($p < 0.010$)	Significant increase in extent of proteolysis with higher temperatures ($p < 0.010$)		

Author	Cheese type	Control maturation temperature (°C)	Sample storage temperature (°C)	Key findings				
				Rheology / texture	Composition	Biochemical changes	Sensory/ organoleptic attributes	Microbiological changes
Bertola *et al.* (1996)	Mozzarella	4	- 20	No significant difference in the apparent viscosity (AV) was noted at 6 or 14 days frozen storage From 21 days frozen storage AV decreased	NI	NI	NI	NI
Folkertsma *et al.* (1996)	Cheddar	8, 12 or 16	Variations of 8 or 16°C for up to 9 months	Cheese softened more extensively at more severe ripening temperatures/ time regimes	NI	Extent of proteolysis and lipolysis was increased at 16°C in comparison to lower temperatures	Cheeses ripened at 16°C had lower (soft) texture scores Flavour intensity increased with more severe temperature/ time regimes	Total bacterial counts decreased by 2-log cycles, while non-starter LAB increased throughout ripening
Macedo *et al.* (1997)	Serra Cheese	5	10			Extent of glycolysis was reduced with increasing ripening temperature		Microbiological counts were decreased with increasing ripening temperature
Roostita and Fleet (1996)	Camembert and Blue Vein	5	10 or 25	Texture softens more rapidly at 25°C than at 10°C	NI	NI	Samples showed a decreased sensory appeal with storage at 25°C than at 10°C	Yeast growth was faster at 25°C, however the cells died off faster than at 10°C

Author	Cheese type	Control maturation temperature (°C)	Sample storage temperature (°C)	Key findings				
				Rheology / texture	Composition	Biochemical changes	Sensory/ organoleptic attributes	Microbiological changes
Roger *et al.* (1998)	Semi-soft cheese	13	4.5	NI	NI	NI	NI	Decrease in the respiration/ growth rate of *Penicillium Camemberti* ($R^2 = 99.0\%$)
Feeney *et al.* (2001)	Mozzarella	-	0, 4, 10 or 15	NI	No significant changes in the fat, protein, moisture, pH, calcium, phosphorous or pH 4.6 soluble Nitrogen At 0°C a significant increase in the salt in moisture was noted	Significant increase in the degradation of α_{s1}-casein with increasing temperature ($p < 0.05$)	NI	NI
Guinee *et al.* (2001)	Mozzarella	-	0, 4, 10 or 15	Decrease in the effect of storage temperature on sample firmness ($p < 0.001$)		Decrease in the effect of storage temperature on intact caseins ($p < 0.001$)	NI	NI

Author	Cheese type	Control maturation temperature (°C)	Sample storage temperature (°C)	Key findings				
				Rheology / texture	Composition	Biochemical changes	Sensory/ organoleptic attributes	Microbiological changes
Verdini and Rubiolo (2002a)	Port Salut Argention Cheese	4	-22	NI	NI	No significant changes in proteolysis immediately following thawing. Level of proteolysis 60 days after thawing proceeded faster than control sample over the same period	NI	NI
Kuo and Gunasekaran (2003)	Mozzarella	7	-21.5	Increase in the meltability and stretchability ($p > 0.005$)	NI	NI	NI	NI
Al-Otaibi and Wilbey (2004)	White Salted Cheese	5	10	NI	NI	Decrease in water soluble nitrogen ($p < 0.05$) Increase in Free Amino Acids ($p = 0.001$)	NI	Total viable bacteria counts, including LAB numbers increased

Author	Cheese type	Control maturation temperature (°C)	Sample storage temperature (°C)	Key findings				
				Rheology / texture	Composition	Biochemical changes	Sensory/ organoleptic attributes	Microbiological changes
Bonaïti *et al.* (2004)	Smear ripened cheese		8, 12 and 16°C	Cheese softened throughout ripening	Dry Matter content and pH increased at the rind at all temperatures, but most significantly at 16°C Ripening Temperature did not have an effect on the weight loss	NI	Best cheese appearance was noted at 12°C	Growth of *D. hansenii* most prolific at 16°C
Van Hekken *et al.* (2006)	Soft Caprine Milk Cheese	-	- 20	Freezing did not have a significant effect on the rheological properties	Moisture, fat, total nitrogen, protein and pH contents did not vary significantly with different storage durations	Protein and peptide levels were not significantly affected between different storage durations	NI	NI

Storage temperature* (°C) = the alternative temperature at which the study investigated
NI = Not Investigated

Freezing is defined as the state of a food product where the temperature has been reduced to a point when the products water begins to freeze and forms ice. The internal temperature is lowered below the initial freezing point to -18^{o}C or below, and is one of the most effective treatments to ensure high quality food product (Robertson, 1993; Dinçer, 2003). Freezing foods helps to preserve their shelf life, flavour, colour and nutritive value and is moderately effective for the preservation of texture (Dinçer, 2003; Kuo and Gunasekaran, 2003). Several authors (Lück, 1977; Kuo and Gunasekaran, 2003) have suggested freezing as a suitable method to decrease the rate of ripening and prolong the shelf life of commercially produced cheeses. The freezing point of cheese (the temperature at which the free water in the cheese forms ice crystals) depends on the concentration of dissolved salts and the degree of ripening. In most food products, this is best achieved when the freezing is done rapidly, especially though the 0 to 5^{o}C temperature range (Lück, 1977; Cervantes *et al.,* 1983; Bertola *et al.,* 2000; Dinçer, 2003; Kuo and Gunasekaran, 2003).

2.4.4.1 Effect of temperature on texture of cheese

Methods for measuring the various textural attributes of cheese are shown in **Table 2.4** to **Table 2.6**.

All cheeses soften with increasing temperature (Lucey *et al.,* 2003). According to Guinee *et al.,* (2001) and Lucey *et al.,* (2003) at increased temperatures the thermal motion of the intrinsic molecules and particles leads to an increase in the level of proteolysis and consequently the softening of the cheese. **Table 2.3** indicates that when the ripening temperature was increased, the product generally had a "poor" texture, which develops at a faster rate with increasing storage temperature (Yamamoto *et al.,* 1968; Roostita and Fleet, 1996; Bertola *et al.,* 2000).

Table 2.4: Experimental conditions used in puncture tests for various soft cheeses

Author	**Cheese variety**	**Temperature** (°C)	**Geometry**	**Penetration rate** (mm/min)	**Penetration depth** (mm)	**Measured parameters**
Vassal *et al.*, (1986)	Camembert	20	2mm diameter needle	25	5	Measurements taken from the rind and the centre of the wheel
Macedo *et al.* (1997)	Serra	23	5mm plunger	50	25	Fracture force
Breuil and Meullenet (2001)	A range of cheese varieties including Mozzarella	7	2mm aluminium needle probe	60	10	-
Sousa and McSweeney (2001)	Cooleeney	16	6mm diameter stainless Steel Cylinder	12	10	Fracture force Firmness

Table 2.5: Experimental conditions used in rheological tests for various cheeses

Author	Cheese variety	Temperature (^oC)	Geometry	Sample dimensions		Measured parameters
				Diameter (mm)	**Thickness** (mm)	
Tunick *et al,* (1991, 1993 a and b, 1995)	Mozzarella	22	Parallel plate	25.4	5	Frequency (0.1 to 100 $rads^{-1}$) 0.8% Strain
Sousa and McSweeney (2001)	Cooleeney	16	Cross Hatch Flat Plate	20	5	Storage Modulus (G′) Loss Modulus (G″)
Van Hekken *et al.* (2005)	Chevre	22	Parallel plate	25.4	5	Frequency (0.1 to 100 $rads^{-1}$) 0.8% Strain

Table 2.6: Experimental conditions used in uniaxial compression testing of cheese

Author	**Cheese variety**	**Crosshead speed** (mm/min)	**Temperature** (^oC)	**Sample diameter,** D (mm)	**Sample height,** L (mm)	**Analyses**
Sharma and Sherman (1973)	Gouda and Stilton	50, 200, 500 and 1000	20.5	15	15	Force decompression (10, 20, 50, 75 and 90% of original height)
Chen *et al.* (1979)	Cheddar, Colby, Swiss, Mozzarella, Edam and Gouda	25	≈ 12.5	-	-	Based on force-displacement measurements the hardness, cohesiveness, gumminess and adhesiveness were measured
Cervantes *et al.* (1983)	Mozzarella	15	Room temperature	20 x 20 (cubic)	20	Force decompression (75 – 85% of original height)
Kfoury *et al.,* (1989)	Camembert and St-Paulin	20	20	14	10	Force Decompression (80% of original height)
Tunick *et al,* (1991, 1993 a and b, 1995)	Mozzarella	50	23 – 26	14	14	Force decompression (75% of original height)
Jack *et al.* (1993)	Cheddar	10 and 20	20	15	20	Force decompression (10% and 60% respectively of original height)
Antoniou *et al.,* (2000)	A range of French soft cheeses including Brie and Camembert	10 and 50	20	21	21	Force decompression (10% and 80% respectively of original height)
Bertola *et al.,* (2000)	Gouda	100	-	17	25	Force Decompression (80% of original height) Relaxation curves (over 300s)

Author	**Cheese variety**	**Crosshead speed** (mm/min)	**Temperature** (°C)	**Sample diameter,** D (mm)	**Sample height,** L (mm)	**Analyses**
Guinee *et al.,* (2000)	Cheddar	50	Room temperature	30	29	Force decompression (75% of original height) - "firmness" Force applied per unit area to induce fracture-"Fracture Stress"
Guinee *et al.,* (2001)	Mozzarella	50	8	29	29	Force decompression (30% of original height)
Breuil and Meullenet (2001)	A range of cheese varieties including mozzarella	60	7	-	-	Force decompression (70% of original height)
Boutrou *et al.,* (2002)	"Soft Cheese"	120	≈ 22	40	30	Strength at 5mm Displacement and force at rupture Young's Modulus
Verdini and Rubiolo (2002a)	Port Salut Argentino	10	21	-	-	Force Decompression (40% of original height)
Al-Otaibi and Wilbey (2004)	White Salted Cheese	120	20	20	20	Force Decompression (50% of original height
Kilic and Isin (2004)	Dil Cheese	50 and 200	4	15 x 15 (rectangular)	60	Force as peak force Energy at Failure (area under curve)
Van Hekken *et al.* (2005)	Chevre	100	22	14.5	14.5	Force decompression (75% of original height) The hardness, cohesiveness and springiness were measured from the curves

De Jong (1976) suggested that cool storage may be an effective tool to maintain or hold the desired rheological properties of Meshanger cheese. However, results found from the studies shown in **Table 2.3**, have primarily focussed on the rheological and textural properties of cheese following sub-zero temperatures which has been shown to cause physical breakdown in body and structural characteristics as a result of ice crystal formation. The more rapidly the cheese passes through the freezing zone, the smaller the ice crystals and therefore less damage is done to the cheese microstructure (Lück, 1977; Robertson, 1993; Dinçer, 2003; Kuo and Gunasekaran, 2003). According to Lück (1977) and Verdini and Rubiolo (2002a) rapid freezing for periods of longer than 24 hour hours, and slow defrosting are advantageous. If the freezing conditions are not optimised, the fat or protein matrices may be destabilised and the formation of ice crystals may occur; which have the most detrimental impact on the texture of the product (Lück, 1977; Verdini and Rubiolo, 2002a; Dinçer, 2003).

According to Lück (1977), Kuo and Gunasekaran (2003) and Van Hekken *et al.* (2005) the best results for chilling cheese have been observed where the cheese is stored below $0^{o}C$, but above the actual freezing point, thereby avoiding detrimental effect of the formation of ice crystals, which begin to appear at approximately $-2^{o}C$.

2.4.4.2 Effect of temperature on biochemical reactions in cheese

Methods for measuring the various biochemical reactions in cheese are shown in **Table 2.7** and **Table 2.8**.

Table 2.7: Summary of methods used to measure the degree of lipolysis in soft Camembert-type cheeses

Author	Objectives of study
Woo and Lindsay (1984)	• Quantify the release of Free Fatty Acids at selected time intervals throughout maturation using Gas Chromatography
Addis *et al.* (2001)	• Determine the extracellular lipolytic activities of yeasts and bacteria commercial cheese

Table 2.8: Summary of the methods used to measure the degree of proteolysis in Camembert cheese

Author	Objectives of Study	Nitrogen Determination	Free Amino Acid Analysis	Enzymatic Activity
Gripon *et al.* (1977)	• Determine the role of specific enzymes in the hydrolysis of caseins throughout ripening	TN, pH 4.6 SN, NPN	High Voltage PAGE Electrophoresis	-
Trieu-Cuot and Gripon (1982)	• Characterise the activity of isolated proteoylytic enzymes from a cross section of Camembert cheese	pH 4.6 SN		Isoelectric Focusing
Boutrou *et al.* (1999)	• Determine the proteolytic changes throughout ripening by analysing the expressed juice from cheese	TN, SN and NPN (Kjeldahl method)	2-amino acid analyser	-
Addis *et al.* (2001)	• Determine the extracellular proteolytic activities of yeasts and bacteria commercial cheese	-	-	Evaluated by noting the "clear-zones" on inoculated skim milk agar
Engel *et al.* (2001b)	• Determine changes throughout a cross section of cheese composition throughout ripening	TN, pH 4.6 SN, NPN (Kjedahl method)	-	-
Boutrou *et al.* (2001)	• Determine the degree of proteolysis throughout the manufacture of cheese curd	-	RP-HPLC	-
Sousa and McSweeney (2001)	• Investigate the release of nitrogen fractions throughout the cheese	pH 4.6 soluble and insoluble N	RP-HPLC	-
Boutrou *et al.* (2002)	• Correlate biochemical changes to the structure of the cheese	TN, pH 4.6 SN, NPN (Kjedahl method)	-	-
Guizani *et al.* (2002)	• Determine the biochemical properties of a cross section of cheese throughout ripening	TN, pH 4.6 SN	-	-
Boutrou *et al.* (2006)	• Determine the extent and ripening of cheese over a 27 – day period	SN (Kjedahl method)	2-amino acid analyser	-

SN = Soluble Nitrogen
TN = Total Nitrogen

Increasing the ripening temperature has been shown to accelerate the enzymatic and microbiological processes which lead to the hydrolysis of caseins, peptides, sugars, lipids and subsequently flavour development (Aston *et al.,* 1983b; Fedrick *et al.,* 1983; Jin and Park, 1995; Bertola *et al.,* 2000; Dinçer, 2003). Enzymatic reactions (both chemical and biochemical) and physical reactions continue, even at very low temperatures and the lower the temperature, the slower the speed of the deteriorative reactions, and the better the quality of the final product after defrosting (Verdini and Rubiolo, 2002a; Dinçer, 2003). Dinçer (2003) has indicated that microbiological reactions are stopped at approximately -18^{o}C, while enzymatic reactions are stopped at -24^{o}C.

The results shown in **Table 2.3** indicate that the extent of the release of proteolytic products in cheese is proportional to the severity of the temperature / time treatments. Results from investigations into the extent of proteolysis in mozzarealla cheese showed that at elevated temperatures the concentration of intact caseins significantly decreased (Feeney *et al.,* 2001; Guinee *et al.,* 2001). These results were supported by Fedrick *et al.* (1983) and Aston *et al.,* (1983b) who found that the highest concentration of proteolytic products in cheddar cheese was in those samples which were stored at elevated temperatures. Conversely the concentration of proteolytic products following frozen storage in cabrales cheese had decreased (Alonso *et al.,* 1987)

Quality losses occur because the small amount of unfrozen water in frozen foods provides an environment in which enzymatic and non enzymatic oxidation of lipids and the development of rancidity occur (Fox and Wallace, 1997; Dinçer, 2003; Krochta, 2006). Jarmul *et al.* (1985) showed that with storage at -27^{o}C the changes in fat proceed faster than proteolysis. Whereas Alonso *et al.,* (1987) found no significant difference in the extent of lipolysis of cabrales cheese following frozen storage. According to Fox and Wallace (1997) and Collins *et al.* (2003) lipid oxidation does not occur to a large extent in cheese as a result of its low redox potential (- 250 mV). No additional information was found to indicate the extensive development of rancid notes in Camembert, or similar soft mould ripened cheeses.

The greatest extent of glycolysis occurs throughout the early stages of the cheese manufacture/ ripening process. As a result of this only one study was found to investigate the effect of storage temperature on glycolysis (Macedo *et al.,* 1997). From this study it was found that there was a decrease in the extent of glycolysis at increased maturation temperatures.

2.4.4.3 Effect of temperature on the microbiological changes in cheese

Methods for measuring the microbiological changes in cheese are shown in **Table 2.9**.

Table 2.9: Enumeration methods for yeast and moulds that were isolated from cheese

Author	Micro-organisms	Preparation Conditions			Agar Type	Incubation Conditions	
		Sample size (g)	**Medium**	**Homogenisation Duration** (s)		**Duration** (days)	**Temperature** (^{o}C)
Nuñez (1978)	Yeasts and Moulds	10	90mL 2% (w/v) sodium citrate; 45^{o}C	-	• Potato Dextrose Agar (pH 3.5)	4	26
Nootigedagt and Hartog (1988)	Yeasts and Moulds	20	0.1% (w/v) buffered peptone water; 40^{o}C	60	• Yeast Extract Glucose Agar supplemented with 100µg/mL oxytracylin*	-	-
Marcellino and Benson (1992)	Yeasts and Moulds	-	-	-	• Peptonised-Milk Agar (pH 6.5) • Wort Agar (pH 4.8) • Sabouraud Dextrose Agar (pH 5.6) • Trypic Soy Agar-Glucose (pH 7.3)	-	20
Roostita and Fleet (1996)	Yeasts	10	90mL 0.1% (w/v) peptone	60	• Malt extract Agar supplemented with 100µg/mL oxytracylin*	2 – 4	25
Westall and Filtenborg (1998)	Yeasts	40	360mL 0.1% (w/v) peptone	120	• Plate Count Agar, DRBC and DG18 agar	5	25
Leclercq-Perlat *et al.* (1999)	Yeasts	10g	90mL sterile saline (9g NaCl); 50^{o}C	120	• Yeast-Extract-Glucose-Medium	2 – 3	25

Author	Micro-organisms	Preparation Conditions			Agar Type	Incubation Conditions	
		Sample size (g)	**Medium**	**Homogenisation Duration** (s)		**Duration** (days)	**Temperature** (ºC)
Fox *et al.* (2000)	Yeasts and Moulds	-	-	-	• Yeast-Extract-Glucose-Chloramphenicol Agar	3 – 5	25
Leclercq-Perlat *et al.* (2000)		10g	90mL sterile saline (9g NaCl); 50ºC	120	• Yeast-Extract-Glucose Chloramphenicol Agar • Amphotericin**; Based Lactate Agar	Up to 5	25
Bonaïti *et al.* (2004)	Yeasts	10g	90mL sterile saline (9g NaCl); 50ºC	120	• Yeast-Extract-Glucose Chloramphenicol Agar • Amphotericin**; Based Lactate Agar	Up to 5	25
Leclercq-Perlat *et al.* (2004)	Moulds	10g	90mL sterile saline (9g NaCl); 50ºC	120	• YCG supplemented with 60g NaCl to limit *G. candidum* growth	7	-

* used to inhibit bacterial growth
** used to inhibit fungal growth

During the storage of chilled foods, the microbial flora of the product does not become static, but is affected by many factors, principally the time and temperature of the storage regime. If a microorganism is stored below its minimum growth temperature, gradual death may occur, but often the microorgansim will survive and will resume growth if the temperature is raised (Walker and Betts, 2000). Therefore, when decreasing the storage temperature of a mould ripened cheese such as Camembert, it is important that the storage temperature is above that of the minimum growth temperature of the microflora which makes a significant contribution to the maturation of the product.

In Camembert, one of the most important classes of microorganisms involved in the ripening of the cheese is the moulds which according to Lück (1977) are able to continue to grow at temperatures between -3^{o}C and 0^{o}C. Research conducted by Roger *et al.* (1998) has shown that the respiration/ growth rate of *Penicillium camemberti* is strongly temperature dependent, and as the temperature decreases, the growth rate also decreases.

Yeasts are also important in the maturation of Camembert cheese. According to Walker and Betts (2000), many yeasts may continue to grow at temperatures of less than 0^{o}C. The potential for the growth of yeasts throughout storage was investigated by Roostita and Fleet, 1996. It was found that the population of *Debaromyces hansenii, Candida catenulate, C. lipolytica, C. kefyr, C. intermdiea, Saccharomyces serevisiae, Cryptococcus albidus* and *Kluyveromyces marxianus* yeast species increased by up to 100-fold throughout storage at both 10^{o}C or 25^{o}C. Growth at 25^{o}C was found to occur faster, however cells began to die off after reaching maximum populations of 10^6 – 10^8 cfu/g, indicating that a greater stress on the intrinsic factors (lower A_w and higher salt concentrations) within the cheese were occurring at increased temperature. Storage at 10^{o}C showed a slower growth rate over a longer period and in some cases the total population exceeded that of the maximum population at 25^{o}C.

No studies were found that investigated the growth of yeasts and moulds at temperatures of less than 0^{o}C. However, according to Fox *et al.* (2000) the optimum relative humidity and temperature range which facilitates the growth of both yeasts and moulds is higher than 95% and 12 – 20°C respectively.

2.4.4.4 Effect of temperature on the organoleptic properties of cheese

Methods for measuring the changes in the organoleptic properties of cheese are shown in **Table 2.10** and **Table 2.11**.

The products of biochemical reactions, such as proteolysis and lipolysis, contribute to the development of flavours and aromas in cheese. Therefore, the organoleptic properties of cheese which have been subjected to elevated or decreased ripening temperatures is dependent on the extent of reactions which have lead to the hydrolysis of fatty acids and amino acids.

Studies have shown that when elevated temperature/ time combinations are too severe, the extent of ripening of cheddar cheese is limited by the development of undesirable flavours and odours which give low sensory appeal and can collectively contribute to a range of spoilage processes that decrease the shelf life of the product (Yamamoto *et al.,* 1968; Aston *et al.,* 1983b; Fedrick *et al.,* 1983; Marshall and Waugh, 1978; Jin and Park, 1995; Roostita and Fleet, 1996). Alternatively mozzarella cheese, following one week of frozen storage, no significant effect was observed in regard to the sensory properties of the product (Cervantes *et al.,* 1983).

Table 2.10: Common screening methods used for trained panel Quantitative Descriptive Analysis

Test	Objective Measurement	Interpretation of Results
Matching Tests	Determines a candidate's ability to discriminate (and describe) differences between stimuli and their relative intensity	Reject candidates who score: • less than 75% correct matches • less than 60% in choosing the correct descriptor
Detection/ Discrimination Tests	Determines a candidate's ability to detect differences among similar products with ingredient or processing variables. Types of tests used: Triangle tests or Duo-Trio tests	Reject candidates who score: • less than 60% for "easy" tests or less than 40% for "moderately difficult" tests (Triangle tests) • less than 75% for "easy" tests or less than 60% for "moderately difficult" tests (Duo-Trio tests)
Ranking/ Rating Tests for Intensity	Determine a candidate's ability to discriminate between intensity levels for a given attribute	Accept candidates who rank samples correctly <u>or</u> who invert the adjacent pair

Adapted from Meilgaard *et al.* (2007)

Table 2.11: Summary of descriptors used in texture analysis of a variety of cheeses

Author	Cheese Variety	Trained Panel Texture Descriptors and Definitions
Chen *et al.* (1979)	Cheddar, Colby, Swiss, Mozzarella, Edam and Gouda	Hardness – "force required to penetrate the cheese sample with the molar teeth"
		Cohessiveness – " degree to which the cheese sample deforms before rupturing"
		Adhesiveness – "force required to remove the cheese sample that adheres to the mouth surface"
		Chewiness – "time required to masticate the cheese sample at a constant rate of force application to reduce it to a consistency suitable for swallowing"
Cervantes *et al.* (1983)	Mozzarella	Firmness – "resistance of cheese to crushing or deformation"
		Cohessiveness – "ability of cheese to compress with minimum delamination of the fibrous structure of the cheese"
Johnston *et al.* (1994)	Cheddar	*Tactile* Rubberiness – "the degree to which the cheese retruned to its initial form after being pressed between the thumb and forefinger"
		Firmness – " the force required to press a block of cheese between the thumb and forefinger"
		Curdiness – "the degree to which the cheese broke down into small curd-like particles when pressed between fingers"
		Smoothness – "the degree to which the cheese structure fell apart and broke up when rubbed to a uniformly smooth mass between the fingers"
		Mouthfeel Curdiness – "the degree to which the cheese broke down into small particles when chewed in the mouth"
		Stickiness – "the stickiness/ pastiness of the cheese against the palate and around the teeth during mastication"
		Grittiness – "the level of 'grainy' particles perceived when the chewed sample was pressed between the tongue and the mouth palate prior to swallowing"

Author	Cheese Variety	Trained Panel Texture Descriptors and Definitions
Antoniou *et al.* (2000)	A range of French soft cheeses including Brie and Camembert	Hard – "the amount of effort required to puncture the sample with using the molar teeth"
		Elasticity – "the degree of bouncing the sample between two successive bitings"
		Fracturability – "degree of brittleness shown by the sample at the first biting"
		Cohesiveness – "perceived degree of consistency that the sample possessed during biting"
		Adhesiveness – "stickiness of the sample within the mouth throughout mastication"
Breuil and Meullenet (2001)	A range of cheese varieties including cheddar and mozzarella	*Tactile* Chewiness – "energy required to masticate the sample to a state ready for swallowing"
		Springiness – "the rate at which the sample returns to its original shape"
		Hardness – "the force required to compress the sample fully"
		Cohessiveness – "the amount samples deforms rather than splits apart, cracks or breaks"
		Mouthfeel Cohessiveness of Mass – "the amount the chewed sample holds together"
		Roughness of Mass – "the amount of roughness perceived in the chewed sample"
		Moisture Absorption – "the amount of saliva absorbed by the sample during mastication"
		Tooth-Pull – "the force required to separate the jaws during mastication"
		Residual Film – "the amount of residue felt by the tongue when moved over the surface of the mouth"
		Tooth-Pack – "the amount of product packed into the crowns of teeth after mastication"
		Loose Particles – "the amount of particles remaining in and on the surface of the mouth after swallowing"

Both food desiccation and the formation of ice crystals have a negative influence on the appearance and texture of food products (Krochta, 2006) and this is reflected in the research which was conducted by Lück (1977) where it was noted that Camembert cheese developed a brown discolouration and an inferior texture, following frozen storage at -10°C.

2.4.4.5 Effect of temperature on the compositional changes in cheese

Factors of importance in regard to cheese composition include: the moisture content, protein, fat, sodium chloride, milk salts and pH (Lucey *et al.,* 2003). Results from a study by Van Hekken *et al.* (2005) on soft caprine cheese showed that the moisture, protein, fat and salt contents did not correlate significantly with the storage treatment (up to 3 months storage at -20°C and 28 days of storage at 4°C). This was supported by results from an earlier study where the effect of a decreased storage temperature on cabrales cheese was investigated (Alonso *et al.,* 1987). However, in studies where the storage temperature was increased, Bonaïti *et al.,* (2004) found that the pH and dry matter content increased within surface ripened cheeses, and no significant change in water loss of the product was observed.

According to Krochta (2006) the most common quality loss in foods which are subjected to freezing or reduced temperatures is moisture loss. Results from Cervantes *et al.,* (1983) showed that the sodium chloride concentration of mozzarella cheese increased following frozen storage at -15°C. This indicates that frozen storage can desiccate food products, therefore increasing the concentration of salt in the product. According to Robertson (1993) and Boutrou *et al.* (1999), packaging is the most effective method to slow the rate of moisture loss.

2.4.5 Summary of the effect of storage on cheese

Overall it was found that:

1. The texture of cheese softens with increasing temperature. However, structural degradation can also occur as a result of ice-crystal formation in samples which have been frozen.
2. Biochemical reactions are enzymatic and therefore are dependent on temperature. Following frozen storage of various cheeses it was found that the concentration of proteolytic products decreased, indicating that proteolysis had slowed, and conflicting results were found regarding the extent of lipolysis.

3. Most studies investigated the effect of microbiological growth in cheese at temperatures above 0^oC. The survival of yeasts and moulds is dependent on their minimum growth temperature, however it was suggested that moulds are able to continue to grow at -3 to 0^oC.
4. The development of undesirable flavours and aromas in cheese is dependent on the extent of proteolysis and lipolysis. Therefore if these reactions are able to continue, the development of off-flavours is more likely. Frozen storage was also shown to have a negative effect on the appearance of Camembert cheese.
5. Generally no significant differences were noted in the composition of cheese following frozen storage. However, if freezer burn occurs, the moisture content of the product can decrease influencing the concentration of other cheese constituents.

2.5 Conclusions

From this literature review, it can be concluded that:

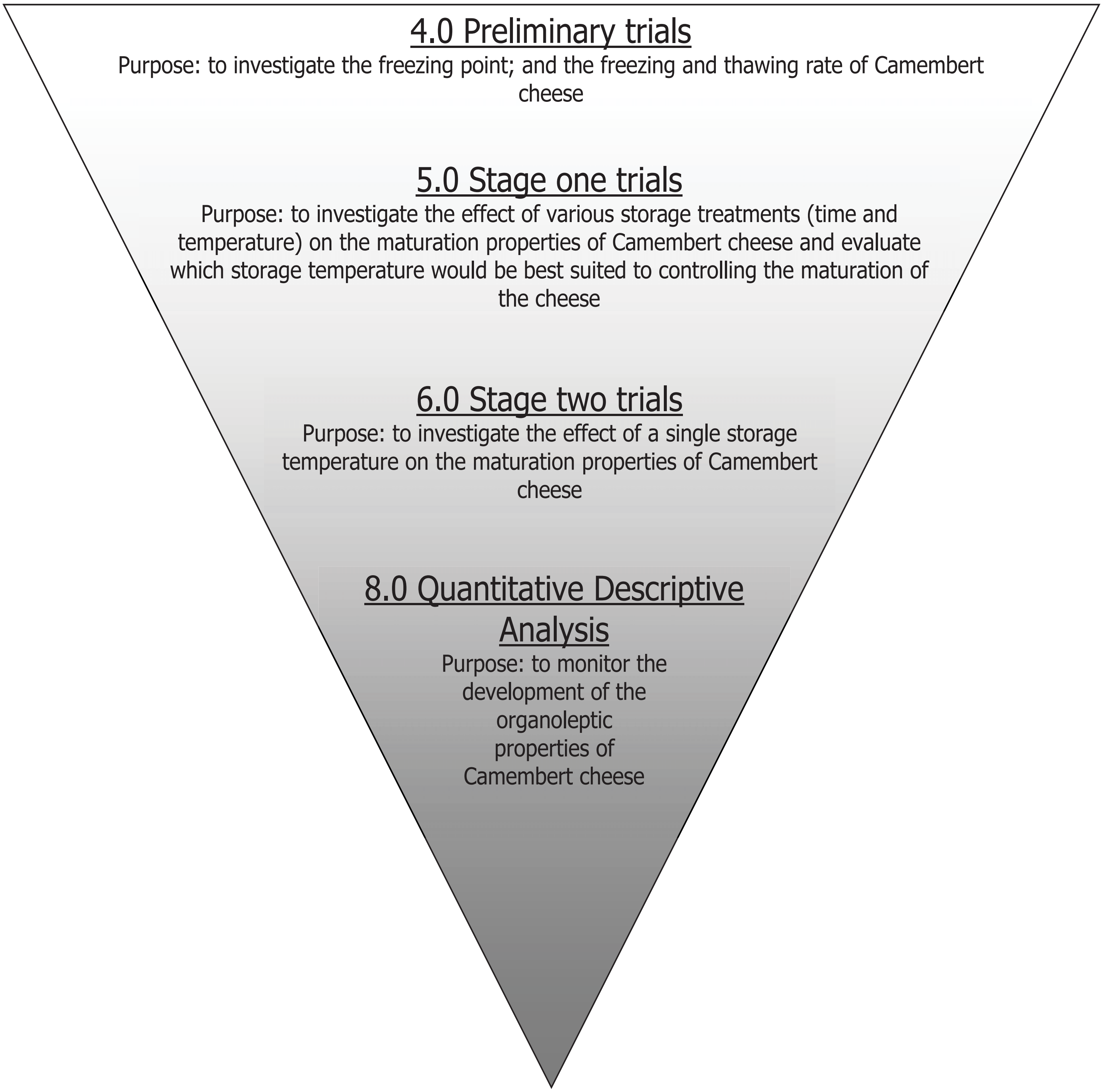
1. Of the entire microflora contributing to the manufacture of Camembert cheese, the *Penicillium* species is most important. This microorganism grows on the surface of the cheese, giving the cheese its characteristic white skin; and is involved in the hydrolysis of a wide range of substrates resulting in curd neutralisation, softening of the cheese and the development of flavours and aromas.
2. Three primary biochemical events take place in the maturation of Camembert cheese and contribute to the characteristic nature of the cheese: glycolysis, lipolysis and proteolysis (the degradation of lactose, fat and protein respectively).
3. Manipulation of various storage conditions can influence certain reactions in the ripening of Camembert cheese. The most widely discussed storage variable was the temperature of the ripening chamber, however other factors such as relative humidity, gas composition and packaging materials were also shown to influence the ripening rate various cheeses.

The extent of cheese maturation could be measured experimentally following a range controlled storage trials. Variables that can be measured may include: the enumeration of viable yeasts and moulds, trained panel evaluation, changes in texture using mechanical testing procedures, the change in pH over time and the quantification of proteolytic products.

3.0 Methodology

3.1 Trial Overview

Practical trials were conducted from approximately the 15 January until the 08 October, 2008. Below is a brief overview of the trials that were conducted in order to meet the objectives of this project.

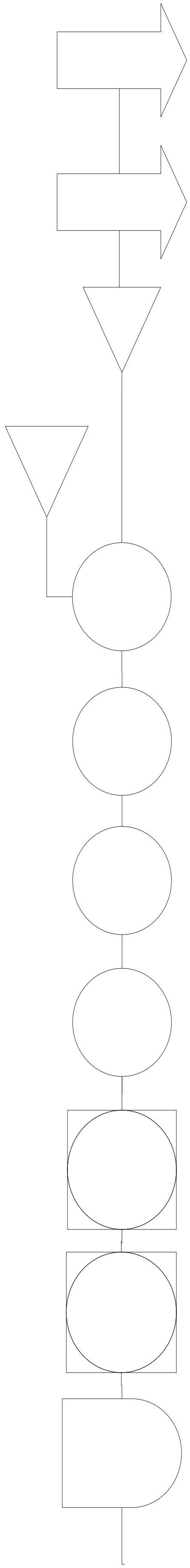


3.2 Materials

The Camembert cheese samples used for this project were sourced from Puhoi Valley Cheese Ltd (see **Appendix: from page 199** for the product specification sheet).

3.2.1 Puhoi Valley Cheese Ltd. manufacture of Camembert cheese

The manufacture process flow for the production of Camembert cheese as used in this project is shown below in **Figure 3.5**. The samples that were used were used in these trials were collected from Puhoi Valle Cheese Ltd. as wrapped units, packed in cardboard cases (12 units per case).



Raw milk is collected from dairy farms by milk tankers and is transported to the Puhoi Valley Cheese Ltd. site.

Milk is unloaded from the tankers by a centrifugal pump system

The raw milk to be used in the manufacture of camembert cheese is stored in one of three 11,000, 15,000 or 22,000L raw milk storage tanks. The raw milk is stored at below 10°C. Each tank is agitated to prevent the cream from separating, this also helps to maintain an even temperature throughout the tank

Storage of cream at ≈4°C

The raw milk is standardised to a target fat: protein ratio of 1.59 (lower limit=1.43, upper limit=1.73) by the addition or removal of cream or skim milk

Milk is pasteurised at 72.5 – 80°C for 15 seconds.

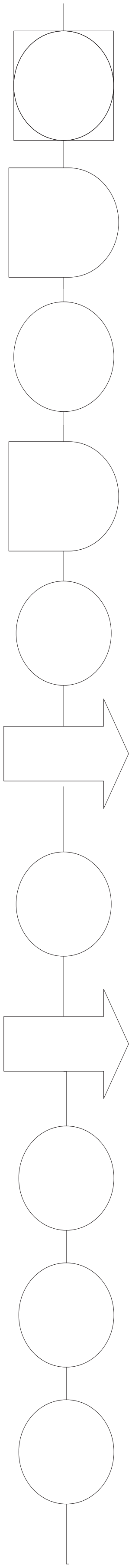
The pasteurised milk is pumped to one of six 3,000L O-Vats where the receiving temperature of post-pasteurisation milk is 38±1°C. In these vats, the milk is continuously stirred at ≈10 rpm.

Starter cultures (x4 units of TS30A and x2 units of 100X), mould (*Penicillium candidum* made up to 300mL volume using Meadow Fresh, blue-top Long Life Milk) and 100mL $CaCl_2$

After 30 minutes (or when the pH reaches 6.60-6.70), 2.5kg Glucona-delta-lactone (GDL), a slow acid release ingredient, is added

After 30-35 minutes (or when the pH reaches 6.40-6.43), 195mL rennet is added, and the vat is continuously stirred for a further two minutes at ≈10 rpm

The stirring function is turned off to allow the curd to set for 30 minutes



When the pH reaches 6.35-6.40 the curd is automatically cut for five minutes at 5.5rpm

Cutting is stopped for 10 minutes to allow the curd to rest

Cutting is resumed for a further five minutes at 5.5 rpm

Cutting is stopped for 10 minutes to allow the curd to rest

Cutting is resumed for a further two minutes at 5.5 rpm

The curd is "hooped" (pumped to the filling machine) at a rate of ≈75L/min

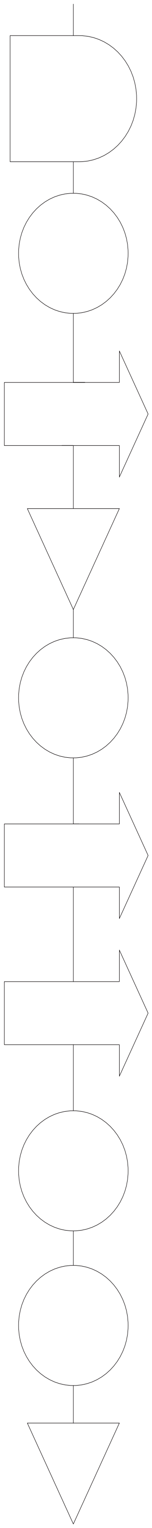
The curd is automatically filled through eight 80x30mm (internal diameter x height per unit) filling molds. Each mold tray holds 16 units.

The mold trays are stacked and transported to the "flip room" (35°C)

The stacked mold trays are collectively and automatically flipped 180° (flip one).

The mold trays are flipped a second time 1.5 hours after flip one, and a third time 6 hours after flip one.

The cheese is manually demolded and the units are stacked on a stainless steel wire racks



The cheese is held in the "flip room" at 35°C until the pH drops to 6.30, and the racks with the cheese are stored in a chiller at 18°C overnight

The cheese units are manually removed from the racks and placed in a saturated salt brine solution (26% salt) at 20°C for ≈20 minutes

The cheese units are removed from the brine solution and put onto stainless steel racks for transportation to the ripening chillers

Cheese is stored at 15°C (≈96% RH) for four days and 14°C (≈96% RH) for six days or until packing.

While in the ripening chillers each unit is manually turned the day after brining (day two) and every second day after that.

The stainless steel racks are transported to a chiller (4°C) for 30-45 minutes prior to packing.

The stainless steel racks are transported to the packing room

Each unit is individually wrapped in permeated white foil wrap with the best before date printed (day/month/year) for seven weeks from the date of packing.

The wrapped units are packed into cardboard cases (12 units per case) and are palletised (182 cases per pallet)

The pallets are stored at Puhoi Valley Cheese Ltd. at 4°C until removal by a refrigerated Goodman-Fielder truck.

Figure 3.5: Process flow for the manufacture of Camembert Cheese at Puhoi Valley Cheese

3.3 Composition of Camembert cheese

3.3.1 Moisture content

A 2-3g test portion of grated cheese sample (combination of rind and centre) was put into clean and dry foil moisture dishes, weighed to five-decimal places and placed in a Contherm Digital Series Incubator (model: 1150C). The incubator was set at 108 ± 1^{o}C and the samples were dried to constant weight, as per AOAC methods for dairy products (Bradley, 2005). The total moisture content of each sample was determined using **Equation 1**.

$$\text{Total Moisture (\%)} = \frac{(C - D)}{C} \times 100 \qquad \textbf{Equation 1}$$

C Initial weight of the grated cheese sample (g)
D Final weight of the grated cheese sample, following drying (g)

3.3.2 pH measurements

The pH measurements were taken from the centre and outer portions of the cheese (see **Figure 3.6**) using a calibrated Sartorius basic pH meter (model: PB-20) with Schott cheese electrode (model: L8880) attachment.

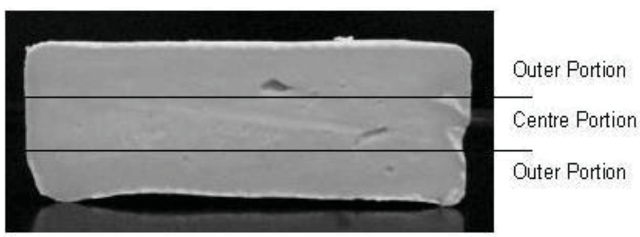


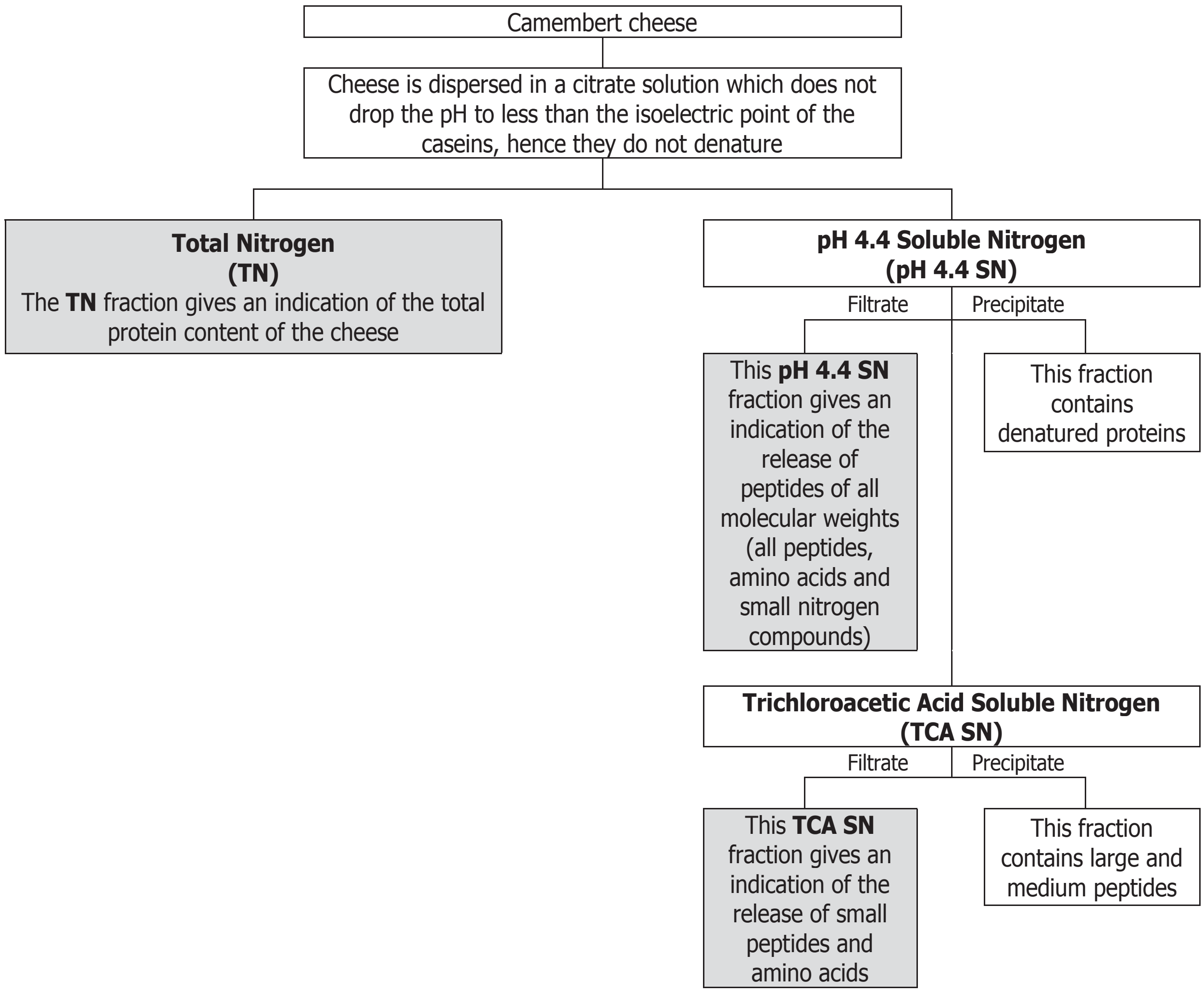
Figure 3.6: Schematic representation of the parts of cheese that were used for outer and centre portion pH analysis

3.3.3 Nitrogen content

Three nitrogen content tests were selected for monitoring the release of various nitrogen fractions over time:

1. Total nitrogen (TN);
2. pH 4.4 soluble nitrogen (pH4.4 SN);
3. Trichloroacetic acid soluble nitrogen (TCA SN).

The relative fractions of pH 4.4 SN and TCA SN increase throughout maturation, and when expressed as a ratio of TN (protein index = pH 4.4 SN/ TN or TCA SN/TN) are useful indicators of the extent of proteolysis in the cheese – **Figure 3.7** shows the fractionation of Camembert cheese and describes what each fraction contains.



Adapted from Bulletins of the International Dairy Federation (Ardö, 1999)

Figure 3.7: Fractionation of the protein content of Camembert cheese

The methods used for determining the nitrogen content of each fraction were adapted from the International Dairy Federation (Ardö, 1999).

Duplicate samples from each storage treatment were tested to determine the degree of proteolysis throughout maturation. Test portions of grated Camembert cheese sample were dispersed in warm 0.5M tri-sodium citrate solution. The cheese/ tri-sodium citrate dispersion was heated and stirred over a magnetic stirrer and hotplate for 60 minutes then cooled to room temperature (20^{o}C) and made to 250mL volume using distilled water. Two 20mL samples of this solution were used for total nitrogen analysis.

Samples from the remaining cheese/ tri-sodium citrate dispersion were fractionated by adjusting the pH to 4.35-4.55 using 1.0M Hydrochloric acid (pH4.4-SN), and the addition of 24% Trichloroacetic acid (TCA-SN). The pH 4.4-SN and TCA SN fractions were filtered and the filtrates, and total nitrogen samples, were used for Kjeldahl analysis (see **Appendix: from page 203** for extended detail of Kjeldahl methodology).

3.4 Texture analysis

Two instrumental texture tests were selected for monitoring the texture of Camembert cheese over time:

1. Uniaxial compression testing (adapted from Kfoury *et al.*, 1989);
2. Puncture testing (adapted from Vassal *et al.,* 1986).

Textural measurements were carried out using the TA-XT2 Texture Analyser (SMS Stable Micro Systems Ltd, United Kingdom), operating in compression mode. All test measurements were analysed using the Texture Analysis TE32 software and samples were assessed when the geometric centre of the cheese had equilibrated to 20 ± 0.2^{o}C. To ensure the cheese was equilibrated, two units were monitored with a calibrated Fluke 51II hand-held electronic thermometer; these cheeses were not used for further testing.

3.4.1 Uniaxial compression testing

Four replicate cylindrical samples from each treatment were cut from the centre of each cheese immediately after the cheese was removed from its respective storage treatment, using a 50mm internal diameter cookie cutter (sample dimensions: height ≈ 15mm).

Measurements were carried out using a 50mm aluminium cylinder probe (Stable Micro Systems Ltd, part code: SMS P/50) and the samples were compressed to 80% of their original height at a rate of 0.33mm/s using an automatic trigger force of 5.0g. The peak force (N) at 80% compression and the area under the curve (N.mm) were recorded for further analysis. A representation of a typical uniaxial compression test curve is shown in **Figure 3.8**.

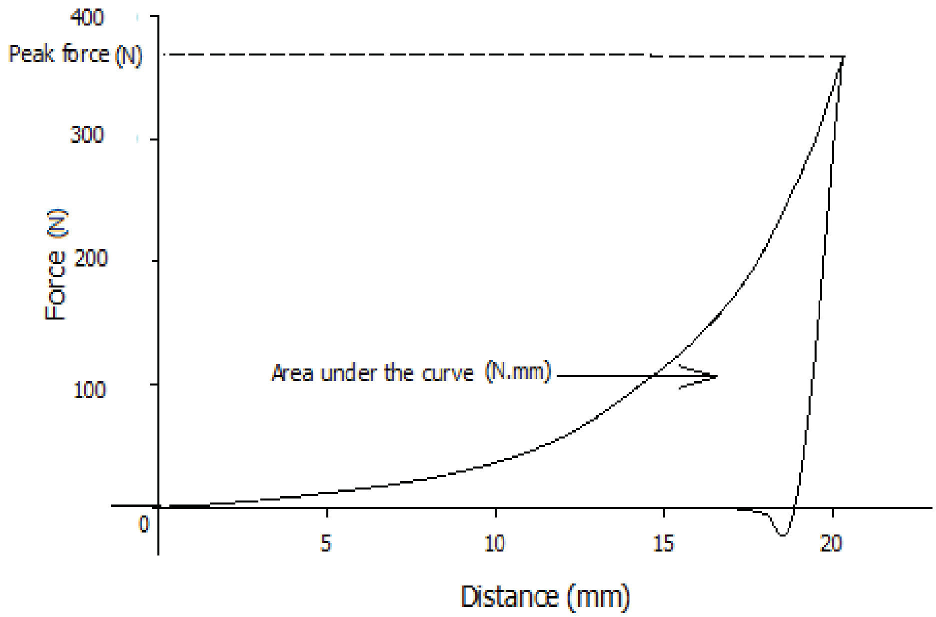


Figure 3.8: Example of a typical uniaxial compression curve

3.4.2 Puncture testing

The test was performed using a 2mm stainless steel needle probe (Stable Micro Systems Ltd, part code: SMS P/2N), a test speed of 25mm/min, an automatic trigger force of 5.0N, and a penetration depth of 5.0mm.

The rind of duplicate Camembert cheese samples were randomly punctured at a 90^{o} angle to the surface of the cheese 15 times on the inner 50mm (inside external surface) and outer 20mm (outside external surface) – see **Figure 3.9**.

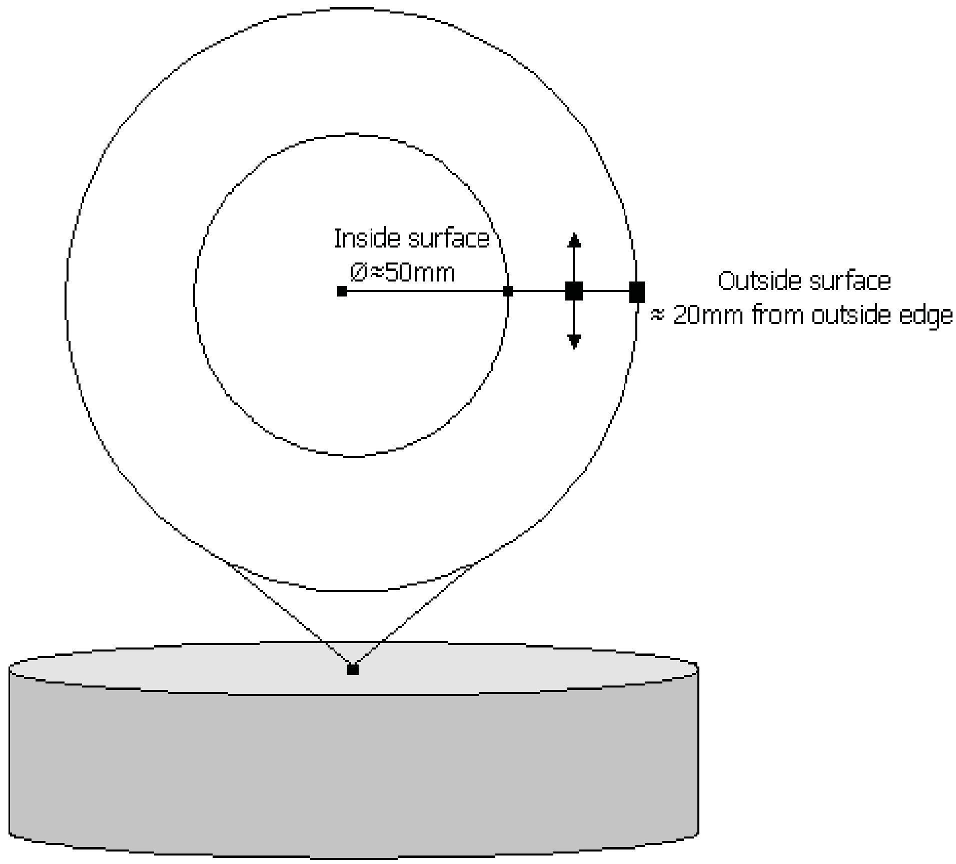


Figure 3.9: Schematic of the puncture test sampling area's for Stage One trials

Two replicate cheeses were punctured a total of 60 times (30 punctures per cheese) to reduce the variability in the data, and the peak force (N) was recorded for further analysis. A representation of a typical puncture test curve is shown in **Figure 3.10**.

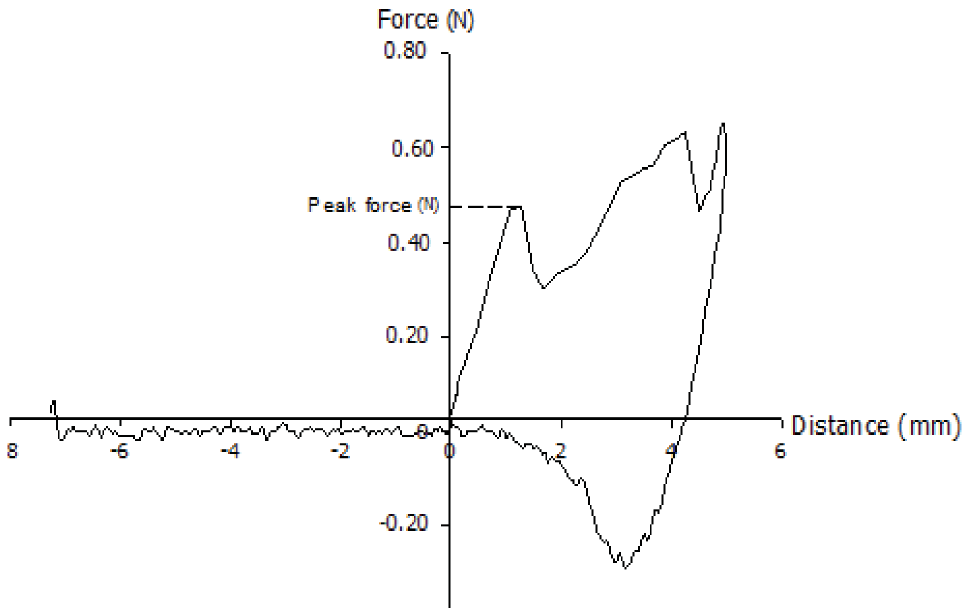


Figure 3.10: Example of a typical puncture test curve

3.5 Yeast and mould enumeration techniques

Viable-cell count-spread plating techniques were used for the enumeration of yeasts and moulds (Swanson *et al.,* 1992).

A 1:10 (w/w) ratio of the rind of Camembert cheese sample and peptone water was placed into a sterile stomacher bag and was homogenised using a Stomacher Lab Blender 400 for 60 seconds. The exact weight of each of the cheese rind and the peptone water was recorded for later calculations. From the homogenised sample (10^{-1} dilution) a 1mL aliquot was transferred to a universal bottle containing 9mL peptone water and was mixed thoroughly.

A 100µL sample of each dilution was aseptically transferred to the surface of an individually labelled PDA agar plate (supplemented with chloramphenicol used for the selection of yeasts and filamentous bacteria (Atlas, 1997)) and was aseptically spread over the surface using a glass spreader (see **Appendix: from page 205** for full detail of media preparation methodology, carried out as per Acuff, 1992). The plates were allowed to dry and were transferred to an incubator set at 25 ± 1^{o}C for five days.

Following incubation, the number of colonies per plate (only plates that contained between 30-300 colonies were counted) were counted and converted to Colony Forming Units per gram of sample (CFU/g) using **Equation 2** below.

$$\text{CFU/g of cheese sample} = \text{number of colonies} \times \frac{1}{\text{dilution factor}} \qquad \textbf{Equation 2}$$

3.5 Quantitative Descriptive Analysis (QDA)

3.5.1 QDA panel training

Prior to the commencement of formal training sessions, panellists were informed of the requirements of their participation in the study and written consent, and a confidentiality agreement was obtained (see **Appendix: from page 255** for a copy of the consent and confidentiality agreement this trial).

All panellists were screened for colour blindness using the Ishihara colour templates (http://www.toledo-bend.com/colorblind/Ishihara.asp), and aroma and taste acuity (as per Meilgaard *et al.,* (2007). See **Appendix: from page 258** for further detail of preparation methods.

Panellists were trained over a five week period, consisting of 12 one to two hour sessions. A total of 13 attributes were identified and used to characterise the changes in Camembert cheese throughout the shelf life and the panel was trained using the quantitative descriptive analysis (QDA®) method as per Meilgaard *et al.,* (2007).

The final list of attributes that were used for the formal QDA panel testing were:

Whiteness of the mould
Dryness of the crust
Mushroom aroma
Dirty/ stale/ cardboard aroma
Ammonia aroma
Springiness of a cross section of the cheese (tactile texture)
Firmness of a cross section of the cheese (tactile texture)
Rind-crunch through a cross section of the cheese (tactile texture)
Bitter flavour
Acidic/sour flavour
Stickiness of the curd (mouthfeel)
Creaminess of the curd (mouthfeel)
Smoothness of the curd (mouthfeel)

3.5.2 QDA panel testing

All sensory testing evaluations were carried out using the sensory analysis booths at Massey University. The individual booths provide a completely controlled environment (temperature set at 20°C and uniform fluorescent white light and ensured independent results between panellists. The panellists were assigned to specific booths for the duration of the trained panel trial, and were presented with blind coded samples (including a blind duplicate to check for reproducibility and a reference cheese picked up fresh from Puhoi Valley Cheese Company Ltd. prior to each session) in a randomised order. Each sample was tempered for two-hours prior to the evaluation session in a controlled temperature room (20 ± 1 °C).

A total of eight evaluations were carried out on a standardised time and day over a 14 week period.

3.6 Consumer research

The subjects used for this research were recruited from the Massey University, Oteha Rohe campus. In total, 49 consumers were used for this trial. All subjects were informed of the requirements of their participation in the trial and written consent was obtained from all subjects (see **Appendix: from page 229** for a copy of the human ethics consent form and questionnaire used for this trial).

The samples were blind coded using three-digit random codes and were tempered for two-hours at 20°C prior to serving. Each sample was presented to the subjects using an incomplete block design (six samples, four were presented to each subject – see **Appendix: from page 231** for more detail) to reduce any variation that may be caused by the order that the samples are judged.

Subjects were asked to judge each sample, using an 11-point scale on the following attributes:

Hedonic scale	"Just about right" scale
Appearance	
Aroma	Intensity of the *aroma*
Flavour	Intensity of the *flavour*
Bitter flavour	Intensity of the *bitter flavour*
Texture	
Creamy Texture	Intensity of the *creamy texture*
Overall Liking	
Likelihood to purchase	

The subjects were also asked to indicate which of the four samples they preferred (see **Appendix: from page 232** for a copy of the questionnaire used for this trial).

3.7 Data analysis

All data was loaded into Microsoft Excel (2007) spreadsheet, was analysed using Minitab version 15, and graphically presented using Sigmaplot version 11.

3.7.1 P-values as a true indication of significance

The p-value gives an indication of how well the data supports the null hypothesis. At the 95% level of confidence, p-values of less than 0.05 are indicative of significant effects and it would be acceptable to predict a correlation between variables 5% of the time, when in fact the variables are not correlated. Similarly at the 99% level of confidence, p-values of less than 0.010 are indicative of significant effects, however with this increase in the level of confidence (99% as opposed to 95%), the likelihood of predicting a specific outcome which is indicating a false is thus reduced.

All results were analysed at the 99.0% level of confidence to minimise the risk of drawing falsely significant conclusions.

4.0 Preliminary trials

4.1 Background

Studies have indicated that storing cheese below 0°C but above the actual freezing point can be an effective method of slowing the ripening process of the cheese; however the formation of ice crystals may have a detrimental effect on the texture of the cheese (Lück, 1977; Kuo and Gunasekaran, 2003; Van Hekken *et al.,* 2005). It has been recommended that rapid freezing, results in the formation of smaller ice crystals, therefore resulting in less damage to the cheese microstructure (Robertson, 1993; Dinçer, 2003; Kuo and Gunasekaran, 2003), and slow defrosting is advantageous (Lück, 1977; Verdini and Rubiolo, 2002a). Therefore investigating the freezing temperature of Camembert cheese is important to the development of an effective storage regime for controlling the maturation of the product.

4.2 Research objectives

The objectives of the current work were to:

1. Determine the freezing point of Camembert cheese;
2. Investigate various methods of modifying the freezing rates and thawing rates of Camembert cheese.

4.3 Methodology

Temperature profiles of duplicate samples of wrapped Camembert cheese were measured during freezing and thawing using custom-made PT100-RTD sensor probes (Teltherm Instruments Ltd., New Zealand). The thermocouples were inserted perpendicularly into the samples, and positioned at approximately the geometric centre (see **Figure 4.11**). A Grant Squirrel data logger (model: 2020-1F8, United Kingdom) recorded the temperature at one-minute intervals and all test measurements were analysed using Squirrel View software. All investigations were carried out using the facilities at Massey University, Albany.

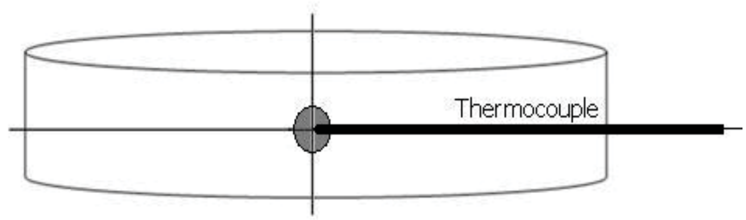


Figure 4.11: Schematic of the geometric centre of a single unit of Camembert cheese

4.3.1 Determining the freezing point of Camembert cheese

The freezing profile of Camembert cheese samples was monitored in a freezer set at -18±1^{o}C.

4.3.2 Evaluation of freezing rates of Camembert cheese

Two treatments were investigated in evaluating the freezing profile of Camembert cheese. These were:

1. By placing individual Camembert cheese samples on a ventilated bread tray (dimensions: 0.60 X 0.595m), set up ≈ 0.30m from the fan unit in a freezer set at -18±1^{o}C;
2. By placing cased Camembert cheese samples (see **Figure 4.12** for the layout of individual units within each case) on a ventilated bread tray (dimensions as above), set up ≈ 0.30m from the fan unit in a freezer set at -18±1^{o}C.

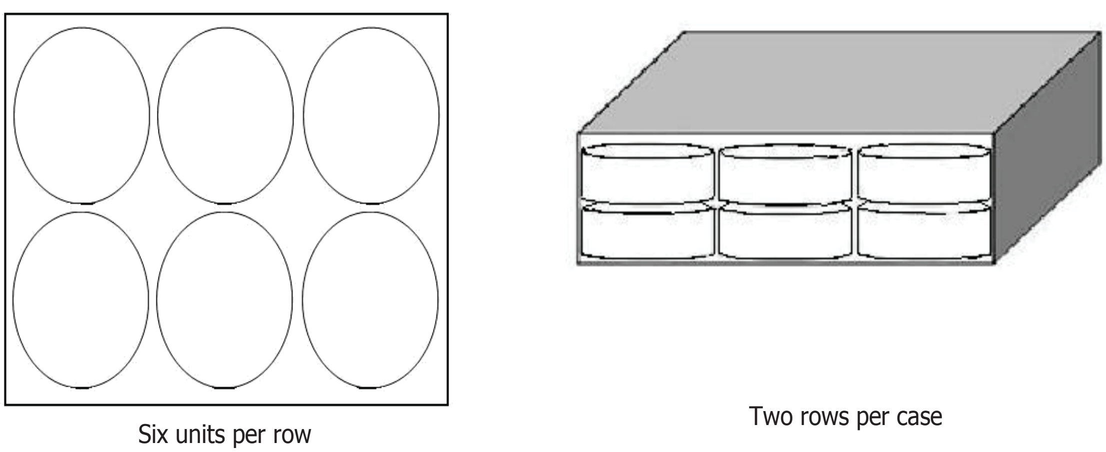


Figure 4.12: Example of the layout of Camembert cheese within each case

4.3.3 Evaluation of thawing rates of Camembert cheese

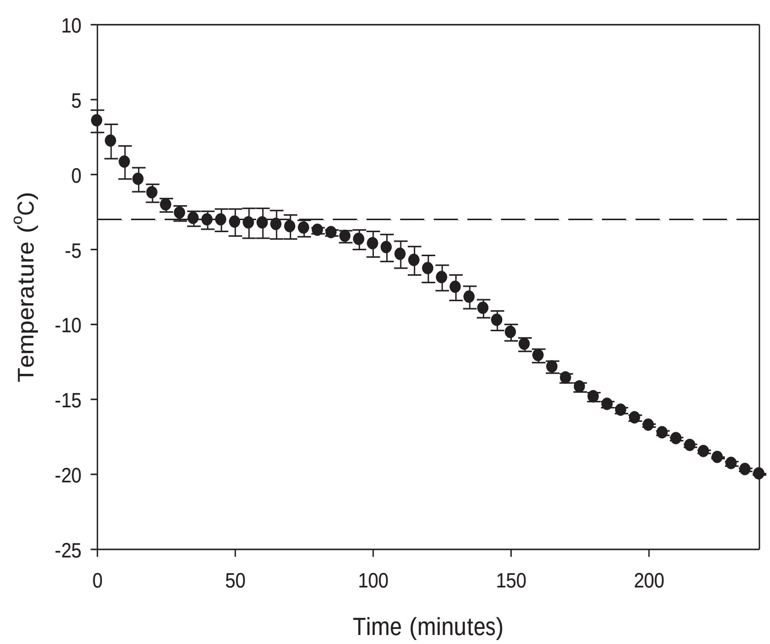
Two treatments were investigated in evaluating the thawing profile of Camembert cheese. These were:

1. By placing individual Camembert cheese samples on a ventilated bread tray, in a chiller set at +4°C;
2. By placing cased Camembert cheese samples on a ventilated bread tray, in a chiller set at +4°C.

4.4 Results and discussion

4.4.1 Freezing point of Camembert cheese

The aim of the current work was to determine the freezing point of Camembert cheese. The freezing profile of Camembert cheese during freezing at ≈ -18.7±0.1°C is shown in **Figure 4.13**.



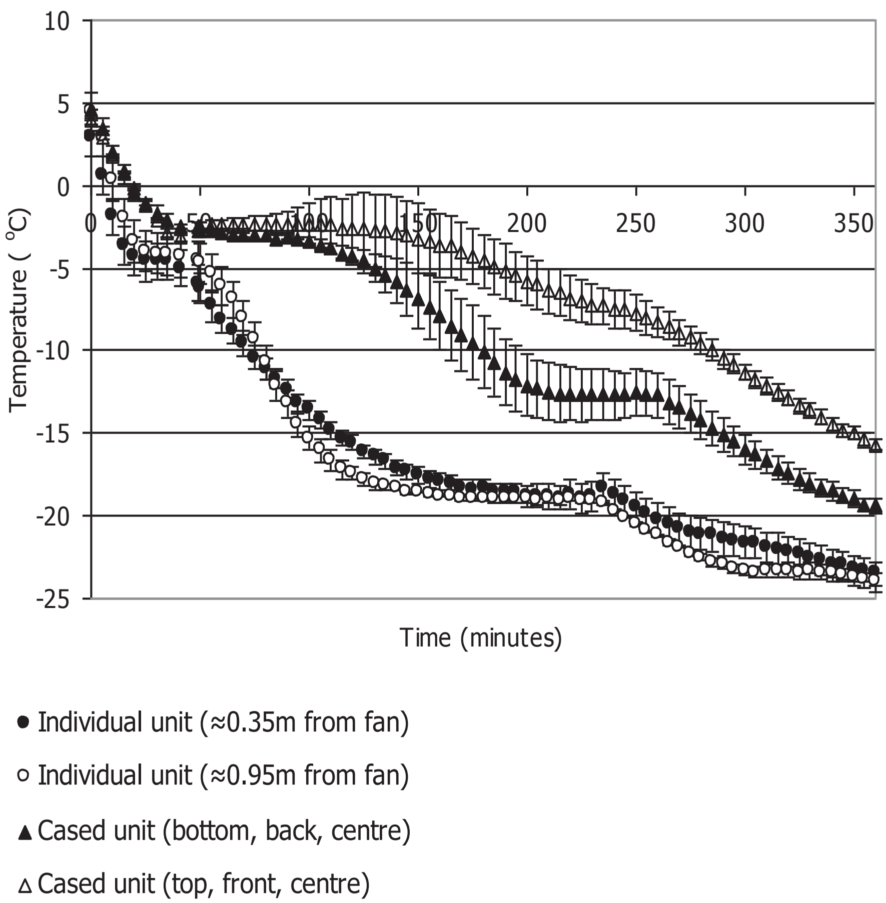
Results are representative of an average temperature of duplicate samples at five-minute intervals ± standard error

Figure 4.13: Freezing profile of wrapped Camembert cheese units over 240 minutes in a freezer unit set at ≈ -18.7±0.1°C

From this **Figure 4.13**, no super cooling was clearly noticeable in the temperature curve of the cheese. The freezing point where the temperature of the geometric centre plateaus as a result of the solidification of the freezable water (Dinçer, 2003) was found to start at -3.0°C and continue to -3.5°C which was achieved after 36 to 69 minutes (respectively). The rate of change through this phase was found to be -0.126°C per minute (R^2 = 93.0%). Lück (1977) reported a similar freezing point for Camembert cheese, indicating that depending on the degree of ripening and the salt concentration, the cheese should freeze at between -2° to -5°C.

4.4.2 Freezing rates

The aim of the current work was to find the fastest method of reducing the temperature of the cheese, as this has been shown to minimise the development of microbiological and enzymatic changes in the food product (Dinçer, 2003) and preserve the texture of the cheese throughout frozen storage (Kuo and Gunasekaran, 2003). **Figure 4.14** shows the freezing rate of wrapped Camembert cheese units in a freezer unit set at ≈ -18.7±0.1°C.



Results are representative of an average temperature of duplicate samples at five-minute intervals ± standard error

Figure 4.14: Freezing profile of wrapped Camembert cheese units over 400 minutes in a freezer unit set at ≈ -18.7±0.1°C

Figure 4.14 and **Table 4.12** collectively show that there is a slight variation between the freezing point of the Camembert cheese samples, which according to Lück (1977) may vary depending on the concentration of dissolved salts and the degree of ripening.

Table 4.12 Summary of the freezing point (°C) and time taken to reach the freezing point (mins) of each freezing treatment

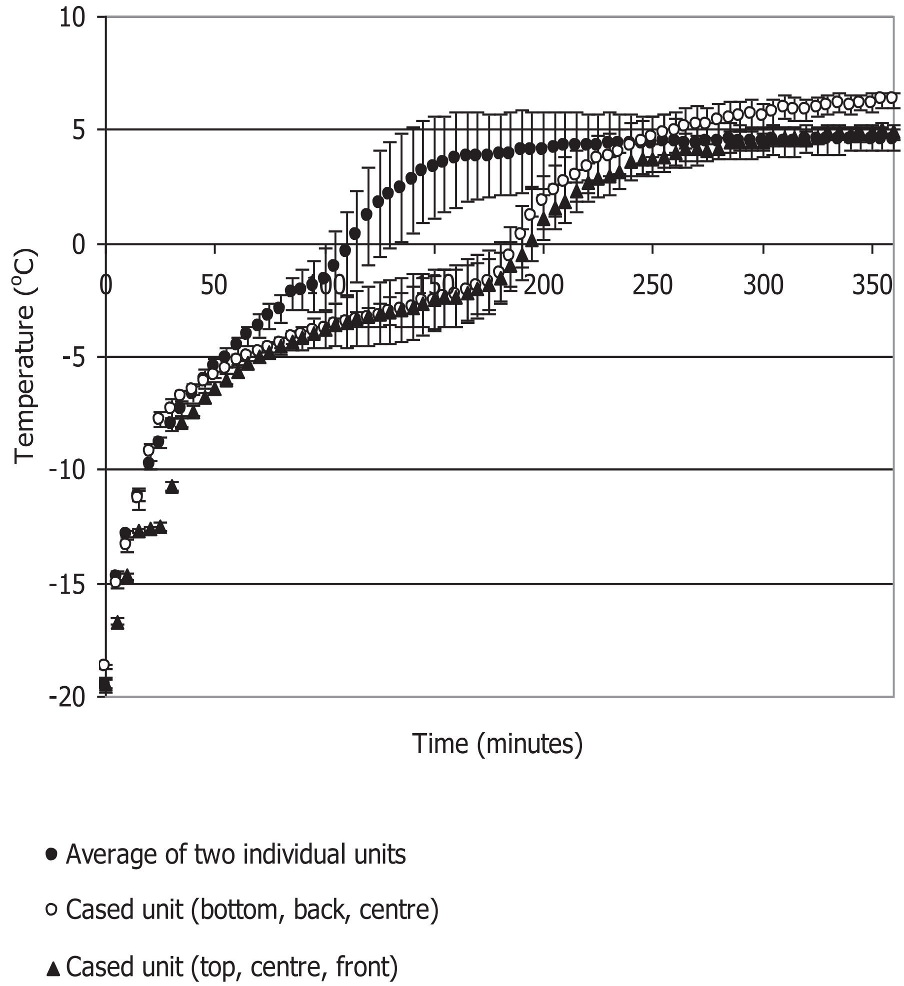
Treatment	**Freezing point** (°C)	**Time to reach freezing point** (minutes)
Individual unit (≈0.35m from the fan unit)	-4.4	23
Individual unit (≈0.95m from the fan unit)	-4.1	26
Cased unit (bottom, back, centre)	-3.0	67
Cased unit (top, front, centre)	-2.3	56

The fastest freezing time is achieved by placing an individual unit of cheese on a ventilated bread tray, ≈0.35m from the fan unit (set at -18.7±0.1°C). According to Dinçer (2007), the freezing time depends on the initial and final temperatures of the product, the physical properties of the product (size and shape), the temperature and air flow velocity of the freezer. Although the air temperature was monitored for each investigation (average air temperature of the freezer unit across all treatments = -18.7±0.1°C). Because of the temperature difference between the air temperature in the case and the freezer during freezing, it can be assumed that the cardboard case had an insulation effect on the freezing rate of the cheese, therefore resulting in a longer time for the geometric centre of the Camembert cheese samples to reach the freezing point.

It is reasonable to assume that the ventilated base of the bread tray would have maximised the air flow around the cheese for each treatment, however it would be recommended that air flow velocity studies be carried out in order to gain a better understanding of the freezing profile of Camembert cheese.

4.4.3 Thawing rates

The aim of the current work was to find the slowest method of thawing the Camembert cheese samples, as this has been recommended by previous authors (Lück, 1977; Verdini and Rubiolo, 2002a). **Figure 4.15** shows the thawing profile of wrapped Camembert cheese in a chiller unit set at +4±1°C.



Results are representative of the average temperature of duplicate samples at five-minute intervals ± standard error

Figure 4.15: Thawing profile of wrapped Camembert cheese units over 450 minutes in a chiller unit set at ≈ +4±1°C

Figure 4.15 and **Table 4.13** collectively show the difference between the profiles of Camembert cheese when subjected to different thawing treatments.

Table 4.13: Summary of the time taken to reach +4°C for of each thawing treatment

Treatment	**Time to reach +4°C** (minutes)
Average (individual units)	193
Cased unit (bottom, back, centre)	424
Cased unit (top, front, centre)	407

The slowest thawing times were observed in the cheese samples that were thawed in the case. Similarly in freezing the cheese samples, it was noted that the cheese at the top, front, centre thawed to +4^{o}C faster because of the ventilation holes in the case (407 minutes), compared to the samples at the bottom, back, centre (424 minutes). According to these data, the cases slow the average rate of thawing to +4±1^{o}C by 222.5 minutes

4.5 Outcomes of preliminary trials

From the results found in this study, it can be concluded that:

1. The freezing profile of Camembert cheese was shown to start at -3.0^{o}C and continue to -3.5^{o}C which was achieved after 36 to 69 minutes (respectively).
2. The most rapid method of freezing was achieved by placing individual units of Camembert ≈ 0.30m from the fan unit in a freezer unit at -18.7±1^{o}C. This was achieved within 23 – 26 minutes;
3. The slowest method of tempering was achieved by tempering the cheese in the cases in a chiller unit set at +4±1^{o}C.

4.6 Preliminary trials conclusions and recommendations

4.6.1 Recommended method of freezing

The fastest chilling time is achieved by placing an individual unit of cheese on a ventilated bread tray, ≈0.35m from the fan unit (set at -18.7±1^{o}C.). The bread tray should be turned 180^{o} half way through the time that it is estimated to reach the required chilling temperature to reduce the variation between the temperatures of the cheeses at the back of the bread-tray, compared to those at the front. Following chilling to the required temperature, it is recommended that the individual cheese units are then packed into the cases for storage at the necessary temperature.

4.6.2 Recommended method of thawing

Following freezing, cheeses should be packed into cases ready to enter the distribution chain. Cheeses can be thawed at +4±1^{o}C while remaining in their cases.

5.0 Stage ONE trials

5.1 Background

Currently Puhoi Valley Camembert cheese has a shelf life of seven to eight weeks from the date of manufacture; however in order for the company to take advantage of new and expanding market opportunities with longer distribution chains trials were carried out to investigate ways to manipulate the shelf life of Bouton d'or Camembert 125g (product code: 569044). Initial discussions with Mr. Rob Scott of Goodman Fielder; Frankton Meats (previously of Ferndale cheese; Fonterra) and Franck Beauvrian of Goodman Fielder; Puhoi Valley Cheese Ltd (previously of National Foods Australia) indicated that holding packaged cheese at -2^{o}C can extend the shelf life of Camembert cheese with no negative impact. Lück (1977) has indicated that holding Camembert cheese samples below 0^{o}C, but above the actual freezing point is an effective form of extending the shelf life. Other suggested methods included freezing the curd prior to molding, manipulating other factors such as the gas composition and relative humidity of the maturation chamber; and manipulating the starter bacteria and surface microflora. For the purposes of this Master's project, it was decided to only focus on investigating the effect of various temperature/ time regimes in controlling the rate of maturation rate of Camembert cheese.

5.2 Research objectives

The objectives of the current work was to investigate which storage temperature (+1^{o}C, -2^{o}C or -10^{o}C) had the most significant effect on the maturation properties of Camembert cheese.

5.3 Methodology

5.3.1 Storage regime for Stage ONE trials

Three storage temperatures (+1±1^{o}C, -2±1^{o}C and -10±1^{o}C respectively, and all were achievable using the facilities at Massey University; Albany). Storage over a four week period was carried out in an attempt to demonstrate the effect of:

1. Storage above 0^{o}C but below the typical maturation temperature (+4^{o}C);

2. Storage below 0°C, but above the actual freezing point (≈3±1°C), as suggested by Lück (1977);
3. Freezing; on the maturation properties of Camembert cheese.

Cheese samples were stored at each temperature for ONE, TWO, THREE and FOUR weeks, followed by maturation at +4±1°C for eight weeks (see **Figure 5.16**).

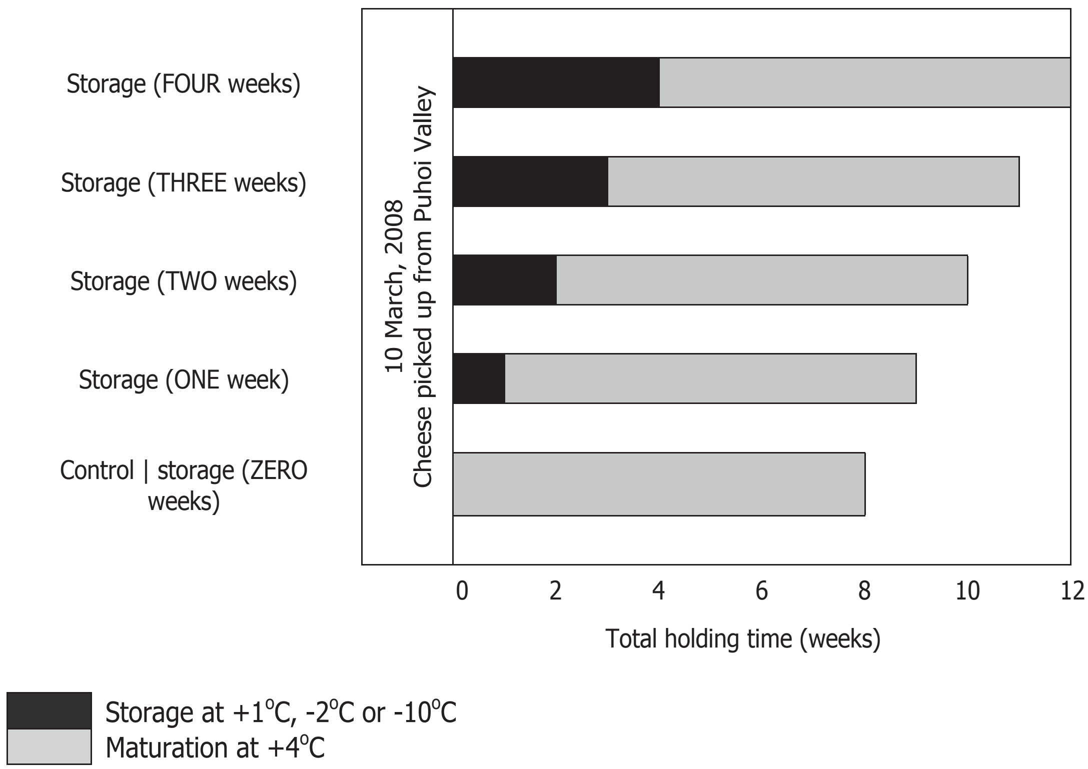


Figure 5.16: Schematic of storage regime of Stage ONE trials

The cheese used for these trials were Bouton d'or Camembert 125g (product code: 569044; batch code: 0203E) and were picked up from Puhoi Valley Cheese Ltd. on 10 March, 2008.

The cheese was categorised into its respective storage treatments (+1°C, -2°C and -10°C) was chilled using the methodology outlined in **Chapter 4.6.1** Recommended method of , and thawed using the methodology outlined in **Chapter 4.6.2** Recommended method of thawing.

Testing included:

Test	Testing frequency	Page
Moisture content	Weekly for control sample; two-weekly for all other samples	64
pH	Weekly for all samples	64
Nitrogen determination	Weekly for control sample; two-weekly for all other samples	64
Uniaxial compression	Weekly for all samples	66
Puncture testing	Two-weekly for all samples	67
Yeast and mould enumeration	Weekly for all samples	69

An error was made in calculating the required concentration of trichloroacetic acid for the determination of TCA SN, resulting in a 4% (w/v) solution being used (or 2% in the final solution) as opposed to 24% (w/v), as suggested by the International Dairy Federation (Ardö, 1999). Trichloroacetic acid is used to determine the quantity of small and intermediate sized peptides in the Camembert cheese, whereby different sized peptides are soluble at different TCA concentrations. Studies have shown that higher concentrations of TCA solutions solubilise a lower number of peptides, therefore resulting lower concentrations of protein to be quantified in the filtrate fraction (Yvon *et al.,* 1989). Studies have also shown that 25% of the total nitrogen (TN) present in skim milk was soluble in 2% (w/v) TCA solutions (Yvon *et al.,* 1989); and 29% of TN in Cheddar cheese was soluble at 2.5% TCA (Reville and Fox, 1978). Similarly, a study by Fox *et al.* (2000) showed that 2% (w/v) TCA solutions precipitates large and intermediate sized peptides in Cheddar cheese, while 12% TCA solution precipitates all but short peptides. The results obtained from these trials (using 2% solution) are higher than those found by Zhao (2006) who used 12% w/v TCA, Engels *et al.* (2001b) who used 12.5% TCA for extraction, and Gripon *et al.* (1977) which used 60% TCA for extraction.

All results for the protein index (TCA SN/TN) for Stage ONE trials were affected by this error. Results reported for subsequent Stage TWO trials have been suitably corrected.

5.4 Results and discussion

The percentage change was calculated between the control samples following eight weeks maturation at +4°C and each of the storage treatment (+1°C, -2°C and -10°C for ONE, TWO, THREE and FOUR weeks) also following eight weeks maturation-see **Table 5.14**. In comparison to the control sample (+4°C for up to eight weeks) **Table 5.14** shows:

- Moisture content (% moisture content) decreased with time across all storage treatments;

- The pH of the inside and outside portions decreased slightly, this was most obvious throughout storage at -10^{o}C storage;
- The protein index (pH 4.4SN/ TN) results decreased for all samples that were treated with +1^{o}C and -10^{o}C storage ranging from ONE to FOUR weeks. However, the -2^{o}C samples were shown to increase slightly. This increase was most obvious with the -2^{o}C storage (FOUR weeks) sample with an increase of 6.58%;
- The -2^{o}C storage samples showed the most obvious increase in the protein index (TCA SN/ TN) results across all treatments. Samples which were treated with -10^{o}C storage showed a decrease in the protein index (TCA SN/ TN) in comparison to the control sample;
- The uniaxial compression work (N.mm) increased for all -10^{o}C storage samples;
- The percentage change observed in the force required to puncture the rind of Camembert cheese samples was close to zero % for samples exposed to +1^{o}C and -2^{o}C for up to FOUR weeks; however samples that were stored at -10^{o}C for up to FOUR weeks decreased from a percentage change of -6.98 to -11.82% for the inside portion and -4.43% to -5.19% for the outside portion;
- The yeast and mould count mostly increased for samples which underwent storage at +1^{o}C and -2^{o}C, however decreased for all samples which were treated at -10^{o}C storage.

Table 5.14: Percentage change (%) of each maturation property following 8 weeks maturation at +4°C when compared to the +4°C control

Storage time	**+1°C storage**				**-2°C storage**				**-10°C storage**			
(weeks)	ONE	TWO	THREE	FOUR	ONE	TWO	THREE	FOUR	ONE	TWO	THREE	FOUR
% Moisture loss	24.35	35.5	37.3	34.0	9.40	23.08	31.11	33.64	-9.92	22.41	14.16	13.40
pH of the inside portion	-6.04	-4.97	4.47	-0.97	3.92	-2.69	-2.12	-1.95	-14.14	-14.03	-13.94	-14.07
pH of the outside portion	-0.10	-0.30	0.00	0.90	2.87	1.06	2.28	3.44	-4.48	-4.28	-4.44	-4.48
Protein index (pH 4.4 SN / TN)	-0.39	-5.52	-6.95	-2.56	2.99	-1.37	0.17	6.58	-5.77	-5.49	-8.88	-15.71
Protein index (TCA SN / TN)	-7.36	8.94	14.29	11.32	14.60	11.48	21.04	30.29	-6.88	-7.06	-2.19	-14.87
Uniaxial compression (work)	-2.09	-1.01	-6.90	-3.05	-2.87	0.45	-7.15	-1.63	3.89	8.94	7.60	11.24
Puncture testing; inside portion	0.05	0.59	-0.26	0.87	-2.19	-0.05	0.18	0.55	-6.98	-7.14	-7.13	-11.82
Puncture testing; outside portion	0.49	0.67	1.40	1.23	0.09	-0.41	-0.10	0.59	-4.43	-5.19	-4.19	-4.69
Enumeration of yeasts and moulds	0.57	-2.10	3.01	7.41	15.05	-1.97	0.17	6.58	-3.42	-25.77	-13.48	-12.58

Results were analysed in Minitab version 15 using the GLM function to determine the significant effects between the maturation properties when Camembert cheese samples were stored at +1^{o}C, -2^{0}C and -10^{0}C for up to FOUR weeks. Storage time, maturation time of the cheese at +4^{o}C, and total holding time (up to 12 weeks; storage time at ZERO, ONE, TWO, THREE or FOUR weeks + maturation time for eight weeks) of the cheese were modelled against maturation properties for each storage temperature. Table of significant effects following each storage treatment are shown in **Table 5.15**, **Table 5.16** and. Graphical representations of the maturation properties from each test with respect to storage treatment are shown in **Appendix: from page 206**.

Table 5.15: Table of significant effects; storage of Camembert cheese samples stored at +1^{o}C for up to FOUR weeks

Maturation property	Storage Time	Maturation time	Total holding time
Moisture content	0.896	0.000	0.000
pH of the inside portion	0.906	0.000	0.000
pH of the outside portion	0.770	0.000	0.000
Protein index (pH 4.4 SN / TN)	0.950	0.000	0.140
Protein index (TCA SN / TN)	0.932	0.000	0.020
Uniaxial compression (work)	0.497	0.000	0.000
Puncture testing; inside portion	0.811	0.000	0.015
Puncture testing; outside portion	0.769	0.000	0.022
Enumeration of yeasts and moulds	0.995	0.000	0.029

Highlighted cells indicate significant effects (p-value < 0.010)

Table 5.16: Table of significant effects; storage of Camembert cheese sample stored at -2^{o}C for up to FOUR weeks

Maturation property	Storage Time	Maturation time	Total holding time
Moisture content	0.912	0.000	0.000
pH of the inside portion	0.995	0.000	0.000
pH of the outside portion	0.999	0.000	0.000
Protein index (pH 4.4 SN / TN)	0.931	0.000	0.198
Protein index (TCA SN / TN)	0.997	0.000	0.107
Uniaxial compression (work)	0.852	0.000	0.000
Puncture testing; inside portion	0.885	0.000	0.042
Puncture testing; outside portion	0.860	0.000	0.020
Enumeration of yeasts and moulds	0.834	0.000	0.041

Highlighted cells indicate significant effects (p-value < 0.010)

Table 5.17: Table of significant effects; storage of Camembert cheese samples stored at -10°C for up to FOUR weeks

Maturation property	Storage Time	Maturation time	Total holding time
Moisture content	0.877	0.000	0.000
pH of the inside portion	0.963	0.000	0.000
pH of the outside portion	0.978	0.000	0.002
Protein index (pH 4.4 SN / TN)	0.965	0.000	0.223
Protein index (TCA SN / TN)	0.996	0.000	0.127
Uniaxial compression (work)	0.821	0.000	0.001
Puncture testing; inside portion	0.882	0.000	0.039
Puncture testing; outside portion	0.876	0.000	0.033
Enumeration of yeasts and moulds	0.773	0.000	0.009

Highlighted cells indicate significant effects (p-value < 0.010)

Table 5.15, **Table 5.16** and

collectively show that at the 99% level of confidence, storage time did not have a significant effect on any of the maturation properties of Camembert cheese at +1°C, -2°C or -10°C that were monitored throughout this study (p-value > 0.010); however maturation time at +4°C did have a significant effect (p-value < 0.010). This indicates that whilst the cheese samples were held within each respective storage treatment (+1°C, -2°C and -10°C for up to FOUR weeks) the rate of the principle microbiological and biochemical reactions which contribute to the characteristic properties of Camembert cheese was controlled; whilst the maturation conditions (+4°C for up to eight weeks) allowed for these reactions to continue.

The results shown in **Table 5.15**, **Table 5.16** and also show that the total holding time had a significant effect on the *pH of the inside portion* (storage at -2°C and -10°C)*, pH of the outside portion* (all storage temperatures), *Uniaxial compression; work* (all storage temperatures) and *enumeration of yeasts and moulds* (storage at -10°C). This suggests that holding Camembert cheese for up to 12 weeks (total holding time and maturation time) has a considerable influence on the maturation profile of these properties. This data, however, does not give an indication of which storage time had a significant effect on the maturation properties of the Camembert cheese samples. A t-test was carried out to determine if there was a significant difference in the mean maturation result of each storage time/ temperature combination with respect to the mean result of the control sample at the 99% level of confidence. If there was no significant difference the two-tails of the mean score would encompass the mean score of the control sample. From this analysis it was found that storage of Camembert cheese samples at -10°C for FOUR weeks resulted in significant effects at the 99% level of confidence for *uniaxial* *compression (work)* and *Enumeration of yeasts and moulds* – see **Table 5.18**. No other storage time/temperature regimes showed any significant effects at the 99% level of confidence; all results from this analysis are shown in **Appendix: from page 227**.

Table 5.18: Results of the two-tailed t-test for mean difference from the control at the 99% level of significance for cheese samples at the end of maturation

Test	Mean score of control sample	-10°C storage (FOUR weeks)
Moisture content	1.049	NSD
pH of the inside portion	5.922	NSD
pH of the outside portion	6.523	NSD
Protein index (pH 4.4 SN / TN)	0.187	NSD
Protein index (TCA SN / TN)	0.113	NSD
Uniaxial compression (work)	1549.46	1556.35 < 1634.57 < 1712.80
Puncture testing; inside portion	0.528	NSD
Puncture testing; outside portion	53.830	NSD
Enumeration of yeasts and moulds	1144232.2	7088202 < 9287854 < 11437507

Control: sample stored at +4°C for eight weeks
NSD = no significant difference
Highlighted cells indicate significant effects (p-value < 0.010)

Table 5.15, **Table 5.16** and show that total holding time had a significant effect (p-value < 0.010) on the *uniaxial compression; work* of Camembert cheese samples that were stored at +1°C, -2°C and -10°C respectively. It has been well researched that cheese softens over time and also that the rate of softening increases with holding cheese samples at higher temperatures (Lück, 1977; Cervantes *et al.,* 1983; Roostita and Fleet, 1996; Bonäiti *et al.,* 2004). However **Table 5.18** shows that at the 99% level of confidence, the mean work required to compress the Camembert cheeses samples to 80% of their original height increased for the samples stored at -10°C for FOUR weeks . Storing the cheese at -10°C for FOUR weeks was the only storage temperature/ time regime which had a significant effect on the texture of the cheese when compared to the control. Few studies were found to investigate the effect of lowering the storage temperature of cheese on the uniaxial compression properties of cheese, however Cervantes *et al.* (1983) showed that following freezing (-15°C) for 21 days, Mozzarella cheese was significantly softer. Similarly research conducted by Lück (1977) showed that Camembert and Brie samples stored between 0°C to -10°C for up to two months had a crumbly outer part with a creamy inner part. Potential ice crystal formation at -10°C (the freezing point of Camembert cheese begins from -3.0°C and continues to -3.5°C, see **section 4.4.1**) may destabilise the fat/ protein matrix at the surface of the cheese (Lück, 1977; Verdini and Rubiolo, 2002a; Dinçer, 2003), therefore having a detrimental effect on the textural properties at the most severe storage temperature/ time combination. This affect is likely to be compounded by the moisture loss that is associated with storing food at freezing or reduced temperatures (Krochta, 2006).

During the storage of chilled foods, the microbial flora of the product does not become static, but is affected by many factors, principally the time and temperature of the storage regime. If a microorganism is stored below its minimum growth temperature, gradual death may occur, but often the microorgansim will survive and will resume growth if the temperature is raised (Walker and Betts, 2000). Therefore, when decreasing the storage temperature of a mould ripened cheese such as Camembert, the storage temperature should be above that of the minimum growth temperature of the microflora as typically as the growth temperature decreases the growth rate also decreases. Research conducted by Lück (1977) showed that the surface moulds of Camembert cheese are able to continue to grow at temperatures between -3°C and 0°C. The combined results shown in and **Table 5.18** indicate that after FOUR weeks storage at -10°C the growth and respiration rate of the surface moulds has been significantly reduced and the yeast and mould counts are shown to be less than that of the control sample. By reducing the concentration of yeasts and moulds following storage this will influence the extent of the important biochemical reactions which contribute to the characteristic appearance, flavour, aroma texture of the product (Leclercq-Perlat *et al.*, 1999). Therefore, the severity of this storage regime has been shown to have a significant effect on the maturation of Camembert cheese samples.

Storage at +1°C and -2°C for up to FOUR weeks did not have a significant effect on the maturation properties of the cheese samples, which would influence the total holding time of Camembert cheese. Therefore these results show that that +1°C and -2°C for up to FOUR weeks can successfully be used to control the rate of maturation in Camembert cheese samples.

5.5 Outcomes of Stage ONE trials

From these trials it was found that:

- Storage time at +1°C, -2°C or -10°C did not have a significant effect on the maturation properties of Camembert cheese samples (p-value < 0.010);
- Total holding time had a significant effect on *pH of the inside portion, pH of the outside portion, Uniaxial compression; work,* and *Enumeration of yeasts and moulds* for samples that were stored at -10°C (p-value < 0.010);

- Storage at +1^{o}C and -2^{o}C were found to be effective at controlling the maturation of Camembert cheese, without having a significant impact on the maturation properties which would influence the maturation profile of Camembert cheese.

6.0 Stage TWO trials

6.1 Background

From the work that was conducted in the Stage ONE Trials (**chapter 5.0**) it was found that storing the cheese at -2^{o}C was effective with respect to controlling the rate of maturation in Camembert cheese. The focus of these trials was to more closely investigate how storage at -2^{o}C impacts the maturation properties and consumer acceptability of Camembert cheese.

6.2 Research objectives

The objectives of the current work were to:

1. Monitor the effect of -2^{o}C storage of Camembert cheese on its properties (composition, biochemical, texture and sensory) throughout maturation at +4^{o}C;
2. Determine the consumer acceptability of Camembert cheese following storage at -2^{o}C and maturation at +4^{o}C.

6.3 Experimental plan

6.3.1 Storage regime for Stage TWO trials

Cheeses were held at a single storage temperature (-2±1^{o}C), over a ZERO, TWO, FOUR and SIX weeks followed by maturation (+4±1^{o}C) for eight weeks using the facilities at Massey University; Albany (see **Figure 6.17**).

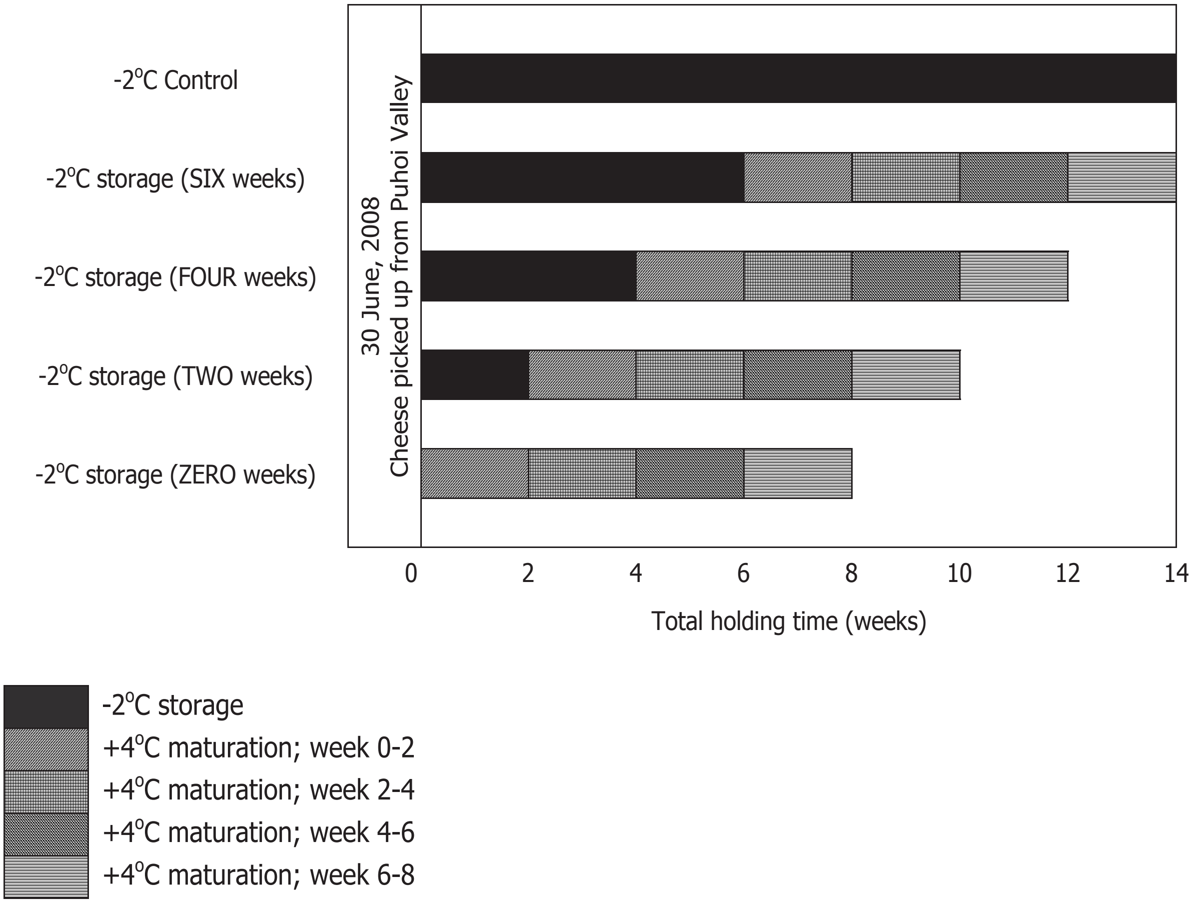


Figure 6.17: Schematic of storage regime of Stage TWO trials

The cheese used for these trials were Bouton d'or Camembert 125g (product code: 569044; batch code: 0203E) and were picked up from Puhoi Valley Cheese Ltd. on 30 June, 2008. The cheese was categorised into its respective storage treatment and the cheese to be stored at -2±1°C was chilled using the methodology outlined in **Chapter 4.6.1** Recommended method of , and thawed using the methodology outlined in **Chapter 4.6.2** Recommended method of thawing.

All testing was carried out two-weekly from the first day of storage. The following compositional, biochemical and textural properties were monitored:

Test	Page
Moisture content	64
pH	64
Nitrogen determination	64
Uniaxial compressions	66
Puncture testing	67

6.3.6 Consumer research

6.3.6.1 Storage regime for Stage TWO consumer trial

A reverse storage trial was used to carry out the consumer research. This allowed samples from each storage treatment to be evaluated on the same day (08 October, 2008), see **Figure 6.18**. Cheeses were held at a single storage temperature (-2±1°C), over a ZERO, TWO, FOUR and SIX weeks followed by maturation (+4±1°C) for eight weeks using the facilities at Massey University; Albany.

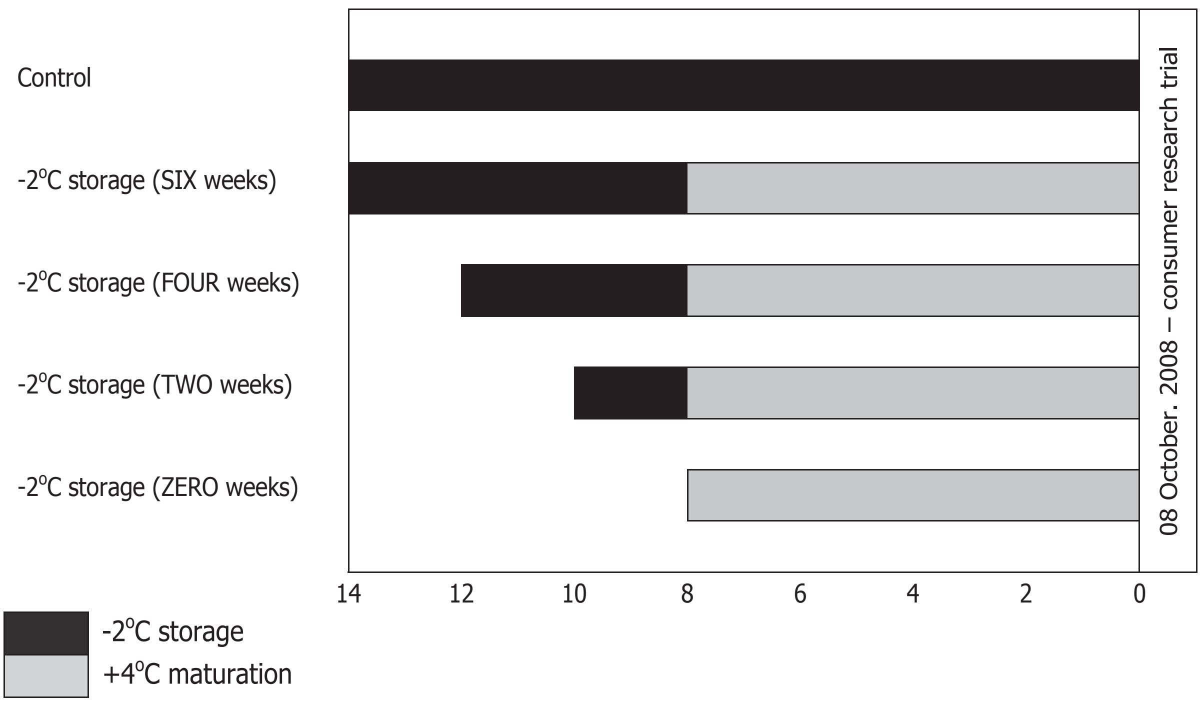


Figure 6.18: Schematic of reverse storage regime of Stage TWO trials

The cheese used for these trials were Bouton d'or Camembert 125g (product code: 569044) and was picked up two-weekly from Puhoi Valley Cheese Ltd. as wrapped units, packed in cardboard cases (12 units per case). All cheeses were collected at approximately the same stage of ripeness.

The cheese to be stored at -2±1°C was chilled using the methodology outlined in **Chapter 4.6.1** Recommended method of , and thawed using the methodology outlined in **Chapter 4.6.2** Recommended method of thawing. Consumers were also given a fresh sample of reference cheese (manufactured on 01 October, 2008). This was picked up from Puhoi Valley Cheese Company Ltd. on the day of the consumer testing.

6.4 Results and discussion

6.4.1 Compositional and textual analysis research

Results were analysed in Minitab version 15 using the GLM function to determine the significant effects of the maturation properties when Camembert cheese samples were stored at -2±1°C for up to SIX weeks. Storage time, maturation time of the cheese at +4±1°C, and total holding time (up to 14 weeks; storage time at ZERO, TWO, FOUR or SIX weeks + maturation time for eight weeks) of the cheese were modelled against maturation properties - **Table 6.19**.

Table 6.19: Table of significant effects; maturation properties of Camembert cheese in relation to storage time at -2°C, maturation at +4°C and total holding time

Maturation property	Storage time at -2°C	Maturation time at +4°C	Total holding time
Moisture content	0.791	0.000	0.002
pH of the inside portion	0.498	0.000	0.000
pH of the outside portion	0.655	0.000	0.000
Protein index (pH 4.4 SN / TN)	0.918	0.000	0.005
Protein index (TCA SN / TN)	0.791	0.000	0.001
Uniaxial compression (work)	0.293	0.000	0.000
Puncture testing	0.867	0.000	0.007

Highlighted cells indicate significant effects (p-value < 0.010)

Table 6.19 shows that at the 99% level of confidence, storage time at -2°C does not affect the maturation properties of Camembert cheese (p-value > 0.010), however maturation time at +4°C does have a significant impact across all of the maturation properties that were investigated (p-value < 0.010).

Moisture content

According to Farkye (2004), semi-soft cheeses, such as Camembert should contain between 39-50% moisture. The average moisture content of the cheeses used in the stage TWO trials was 40.85% (-2°C storage (ZERO weeks); samples stored at +4°C for eight weeks) and 40.59% (Control; sample stored at -2°C for 14 weeks). The change in moisture content throughout storage at -2°C, and maturation at +4°C is shown in

Figure 6.19 and

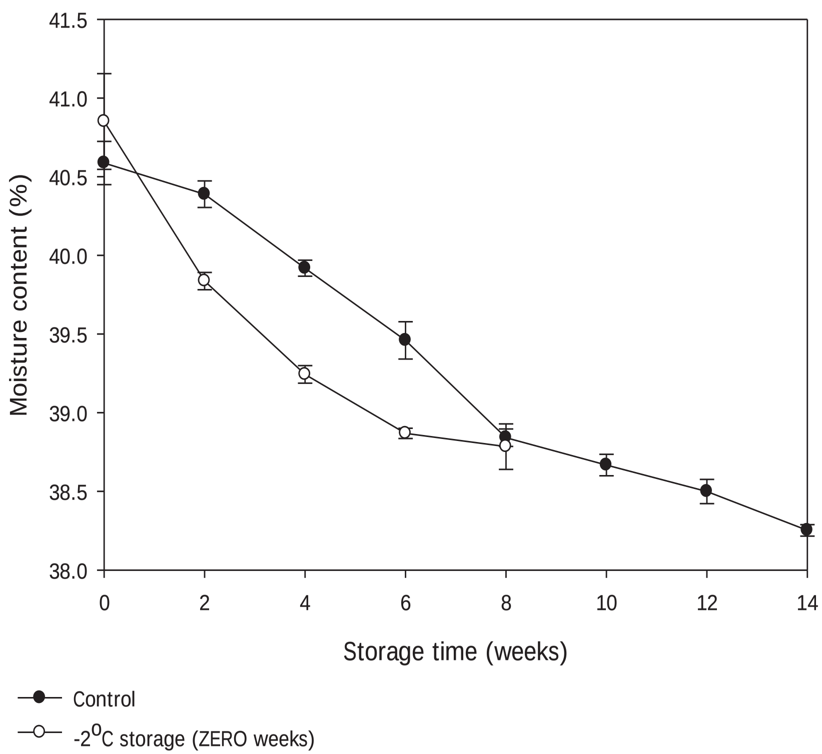
Figure 6.20 respectively. This shows that over time Camembert cheese samples lose moisture during maturation. **Table 6.19** shows that at the 99% level of confidence, storage time -2°C does not have a significant effect on the moisture loss in Camembert cheese (p-value > 0.010); however maturation time and total holding time do have a significant effect on the moisture content of cheese samples (p-value < 0.010) this can be seen by the lower moisture contents at the start of maturation in the cheeses stored for SIX, FOUR and TWO weeks at -2°C. **Table 6.20** shows that the -2°C storage (ZERO weeks) Camembert cheese samples had the highest rate of moisture loss compared to other treatments, therefore demonstrating that -2°C storage reduced the rate of moisture loss throughout maturation at +4°C.

Table 6.20: Rate of change in the moisture content of Camembert cheese throughout maturation at +4°C: moisture content % = [rate] week^{-1} (p-value)

Treatment	**Rate** (week^{-1})	R^2 (%)
Control	-0.179 (0.000)	96.8
-2°C storage (ZERO weeks)	- 0.255 (0.015)	89.3
-2°C storage (TWO weeks)	- 0.198 (0.011)	91.4
-2°C storage (FOUR weeks)	- 0.196 (0.003)	96.6
-2°C storage (SIX weeks)	- 0.206 (0.003)	96.5

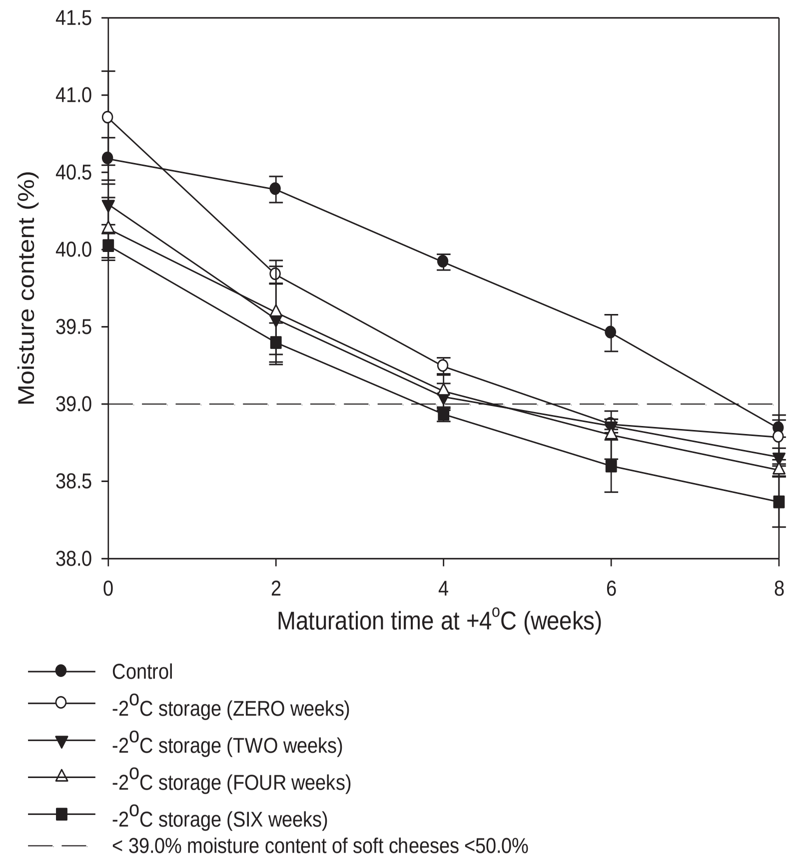
Linear regression was assumed for this analysis
Highlighted cells indicate significant effects (p-value < 0.010)

The results found in this study are supported by authors who investigated the effect of freezing on the moisture content of cheese samples. Van Hekken *et al.* (2005) found no significant difference was found in the moisture content (%) when storing soft Caprine milk cheese samples throughout long term frozen storage at -20°C. Similarly Alonso *et al*. (1987) also showed that storing Cabrales cheese at -40°C, followed by maturation at 9-10°C did not result in a significant difference in the moisture content of the cheeses sampled.



Each data point is representative of an average of duplicate samples ± standard error

Figure 6.19: Effect of -2^{o}C storage on the moisture content (%) of Camembert cheese over 14 weeks



Each data point is representative of an average of duplicate samples ± standard error

Figure 6.20: Effect of -2^{o}C storage on the moisture content (%) of Camembert cheese following maturation at +4^{o}C for eight weeks

pH

In Camembert cheese, the pH increases throughout its shelf life and a pH gradient is established starting from the outside into the centre of the cheese (Engel *et al.*, 2001b). **Figure 6.21** and **Figure 6.23** collectively show that the pH of both the inside and outside portions of the Camembert cheese samples increased throughout storage at -2°C. The pH profile of the inside and outside portion differs, indicating that the rate of biochemical changes which affect pH are different throughout the cross-sectional gradient within Camembert cheese. The rate of change in pH per week in storage at -2°C ZERO weeks was slightly faster than the CONTROL for the outside portion. This is confirmed by results shown in **Table 6.21** where the linear rate of increase was 0.002 week^{-1} greater in the -2°C ZERO week samples. Van Hekken *et al.* (2005) found no significant difference was found in the pH when storing soft Caprine milk cheese samples throughout long term frozen storage at -20°C.

Figure 6.22 and **Figure 6.24** show the evolution of pH in the Camembert cheese samples following storage at -2°C. **Table 6.19** showed that storage time did not have a significant effect on the pH of the centre or pH of the outside portion (p-value > 0.010). Maturation time and total holding time were shown to have significant effect on the pH of cheese samples (p – values < 0.010). The results shown in **Table 6.21** and **Table 6.22** indicate that -2°C storage slowed the rate of pH evolution in both the inside and outside portions of Camembert cheese when compared to the -2°C storage (ZERO weeks); and subsequent maturation at +4°C for all stored cheeses did not affect the rate of pH increase after eight weeks of maturation. Cheeses emerging from storage for TWO, FOUR and SIX weeks did start maturation at higher values than the -2°C (ZERO week) sample, even though the rate of increase was not the same for all cheeses the final pH of these cheeses did eventually reach the same final pH in the centre.

Table 6.21: Rate of change in the inside pH of Camembert cheese throughout maturation at +4°C: pH of the inside portion = [rate] week^{-1} (p-value)

Treatment	**Rate** (week^{-1})	**R^2** (%)
Control	0.151 (0.000)	98.6
-2°C storage (ZERO weeks)	0.223 (0.005)	95.0
-2°C storage (TWO weeks)	0.235 (0.004)	95.4
-2°C storage (FOUR weeks)	0.221 (0.001)	98.3
-2°C storage (SIX weeks)	0.169 (0.003)	96.3

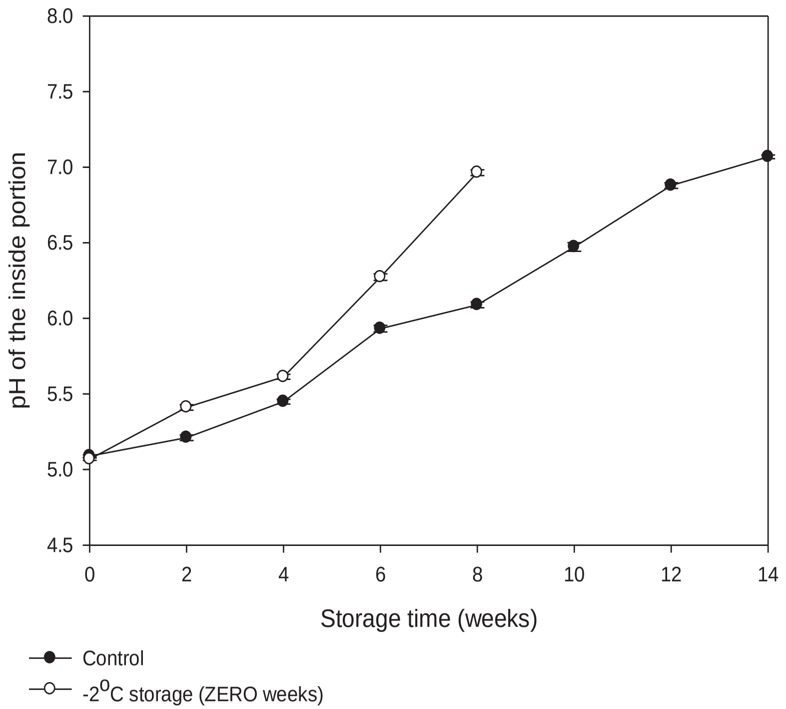
Linear regression was assumed for this analysis
Highlighted cells indicate significant effects (p-value < 0.010)

Table 6.22: Rate of change in the outside pH of Camembert cheese throughout maturation at +4°C: pH of the outside portion = [rate] week^{-1} (p-value)

Treatment	Rate (week^{-1})	R^2 (%)
Control	0.149 (0.000)	95.8
-2°C storage (ZERO weeks)	0.258 (0.022)	86.4
-2°C storage (TWO weeks)	0.206 (0.006)	94.0
-2°C storage (FOUR weeks)	0.126 (0.007)	93.4
-2°C storage (SIX weeks)	0.098 (0.026)	85.1

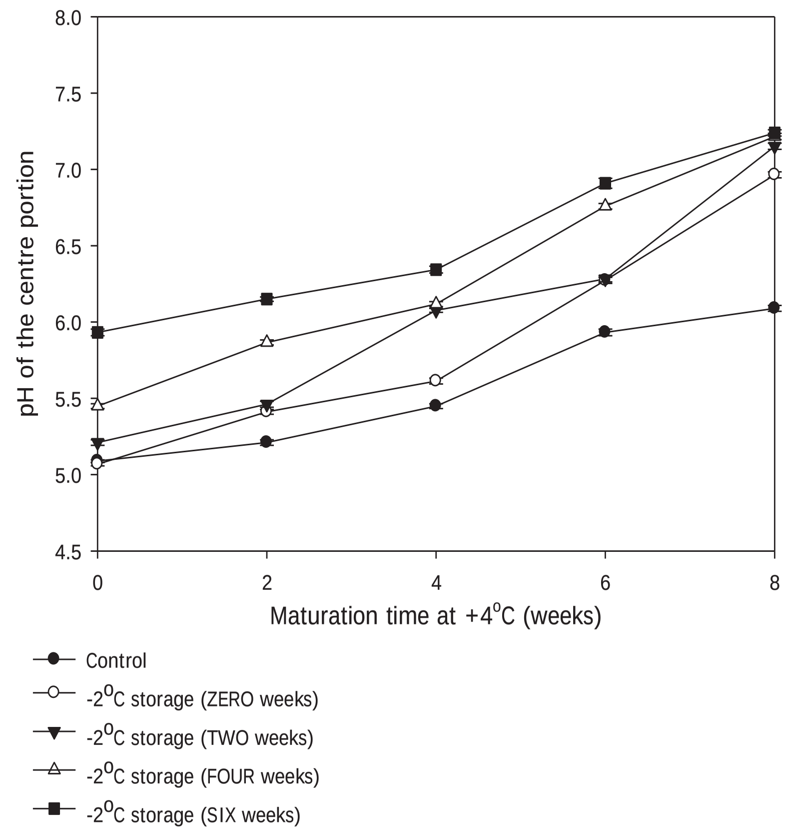
Linear regression was assumed for this analysis

Highlighted cells indicate significant effects (p-value < 0.010)



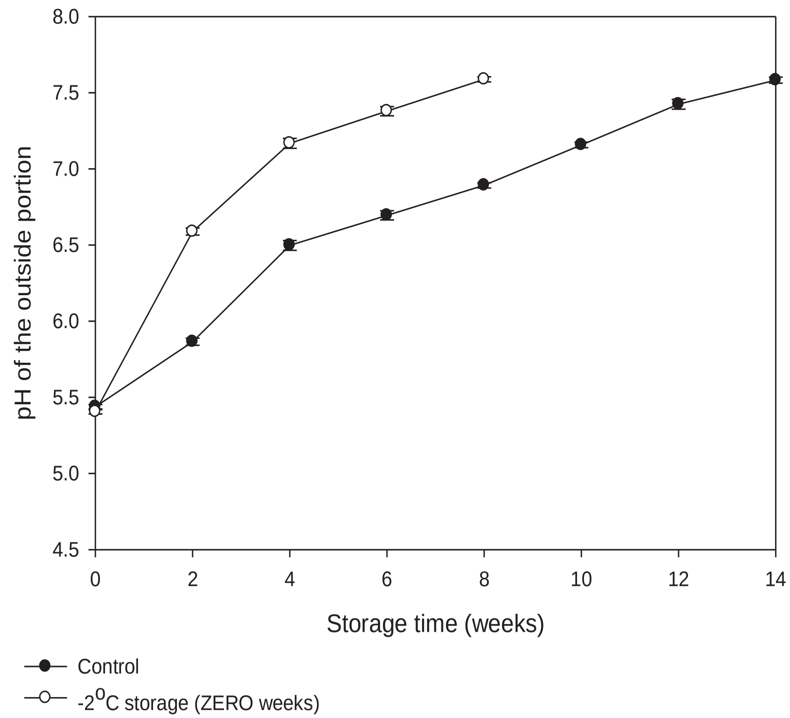
Each data point is representative of an average of duplicate samples ± standard error

Figure 6.21: Effect of -2°C storage on the pH of the inside portion of Camembert cheese over 14 weeks



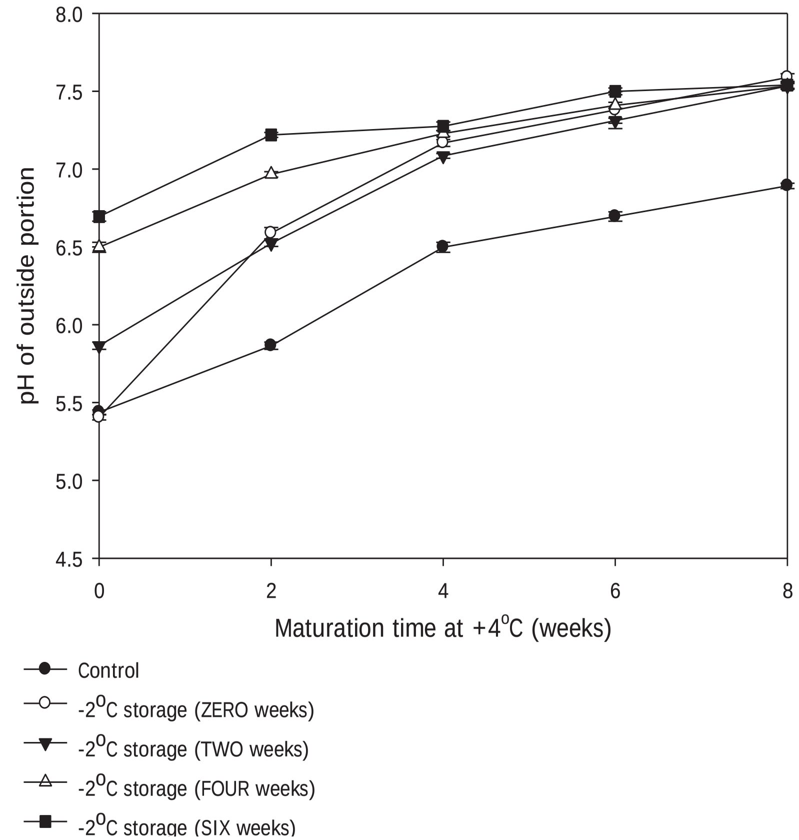
Each data point is representative of an average of duplicate samples ± standard error

Figure 6.22: Effect of -2°C storage on the pH of the inside portion of Camembert cheese following maturation at +4°C for eight weeks



Each data point is representative of an average of duplicate samples ± standard error

Figure 6.23: Effect of -2°C storage on the pH of the outside portion of Camembert cheese over 14 weeks



Each data point is representative of an average of duplicate samples ± standard error

Figure 6.24: Effect of -2°C storage on the pH of the outside portion of Camembert cheese following maturation at +4°C for eight weeks

Protein indices

Figure 6.25 and **Figure 6.27**show the effect of -2°C storage on the pH 4.4 SN/ TN protein index and TCA SN/ TN protein index respectively, of Camembert cheese. Both Figures show an increase in the ratio of pH 4.4 SN/ TN and TCA SN/ TN throughout storage indicating that -2°C did not inhibit the continuation of some degree of proteolysis.

It has been well documented that the rate of proteolysis increases with increasing storage temperature (Alonso *et al.,* 1987; Jin and Park, 1995; Feeney *et al.,* 2001; Van Hekken *et al.,* 2005). This was seen in the stored cheeses as shown in **Figure 6.26** and **Figure 6.28** . **Table 6.23** and **Linear regression** was assumed for this analysis

Highlighted cells indicate significant effects (p-value < 0.010)

Table 6.24 shows that storage at -2°C resulted in increased rates of proteolysis occurring in the Camembert cheese samples throughout maturation at +4°C. This same effect has been reported by Verdini and Rubiolo (2002a) where the release of proteolytic products proceeds faster following frozen storage when compared to the control in Port Salut Argention cheese.

Table 6.23: Rate of change in the pH 4.4 SN/ TN protein index of Camembert cheese throughout maturation at +4°C: pH 4.4 SN/ TN = [rate] week^{-1} (p-value)

Treatment	**Rate** (week^{-1})	**R^2** (%)
Control	0.0085 (0.000)	96.2
-2°C storage (ZERO weeks)	0.0173 (0.001)	98.6
-2°C storage (TWO weeks)	0.0175 (0.002)	97.6
-2°C storage (FOUR weeks)	0.0194 (0.004)	95.3
-2°C storage (SIX weeks)	0.0203 (0.000)	98.4

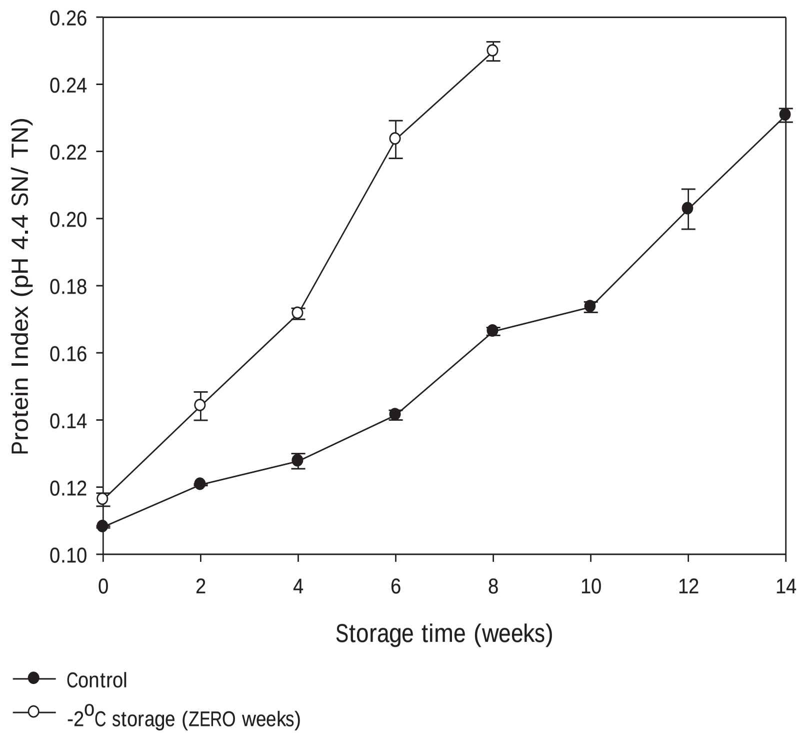
Linear regression was assumed for this analysis
Highlighted cells indicate significant effects (p-value < 0.010)

Table 6.24: Rate of change in the TCA SN/TN protein index of Camembert cheese throughout maturation at +4°C: TCA SN/ TN = [rate] week^{-1} (p-value)

Treatment	**Rate** (week^{-1})	**R^2** (%)
Control	0.00409 (0.000)	96.9
-2°C storage (ZERO weeks)	0.00504 (0.000)	99.8
-2°C storage (TWO weeks)	0.00611 (0.000)	99.2
-2°C storage (FOUR weeks)	0.00895 (0.002)	97.5
-2°C storage (SIX weeks)	0.00972 (0.001)	98.4

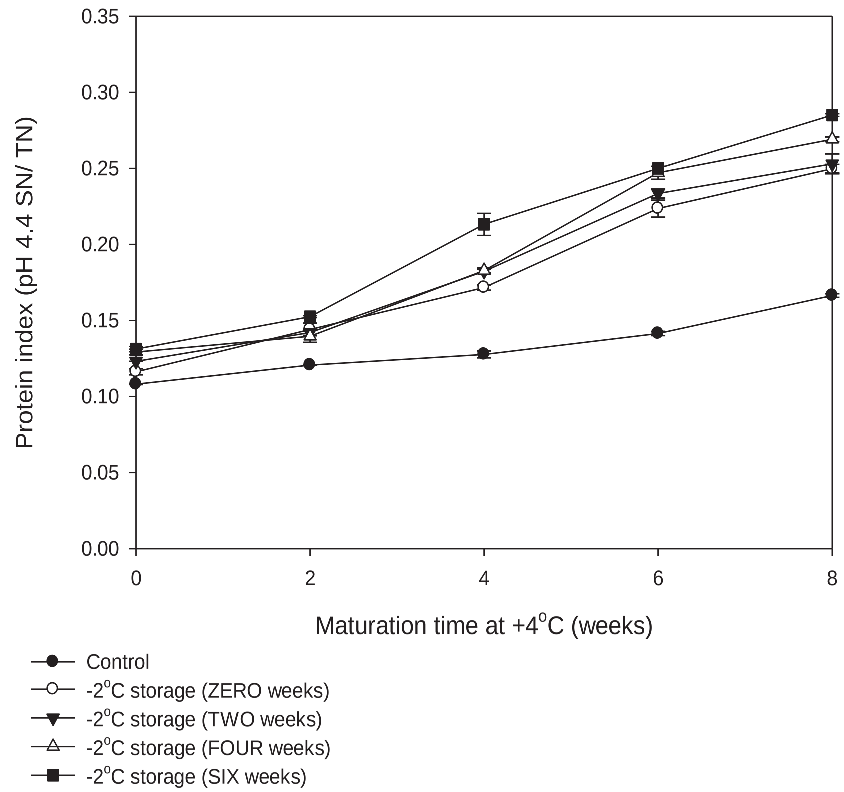
Linear regression was assumed for this analysis
Highlighted cells indicate significant effects (p-value < 0.010)

Table 6.19 showed that maturation time at +4^{o}C had a significant effect on the mean protein indices of both the pH 4.4 SN/ TN and the TCA SN/ TN (p-value < 0.010), therefore this showed that storage at -2^{o}C controlled the rate of proteolysis in Camembert cheese.



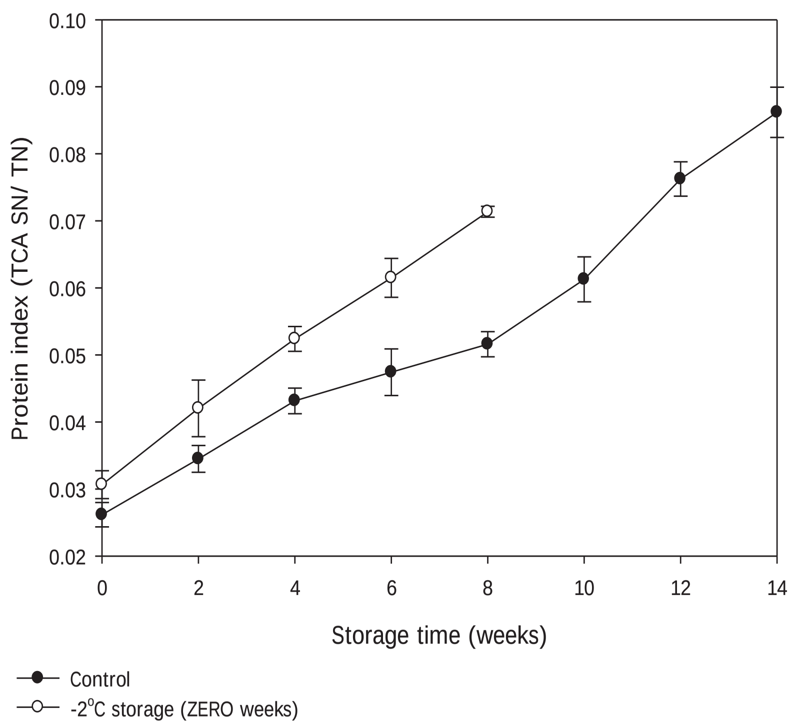
Each data point is representative of an average of duplicate samples ± standard error

Figure 6.25: Effect of -2°C storage on the pH 4.4 SN/ TN protein index of Camembert cheese over 14 weeks



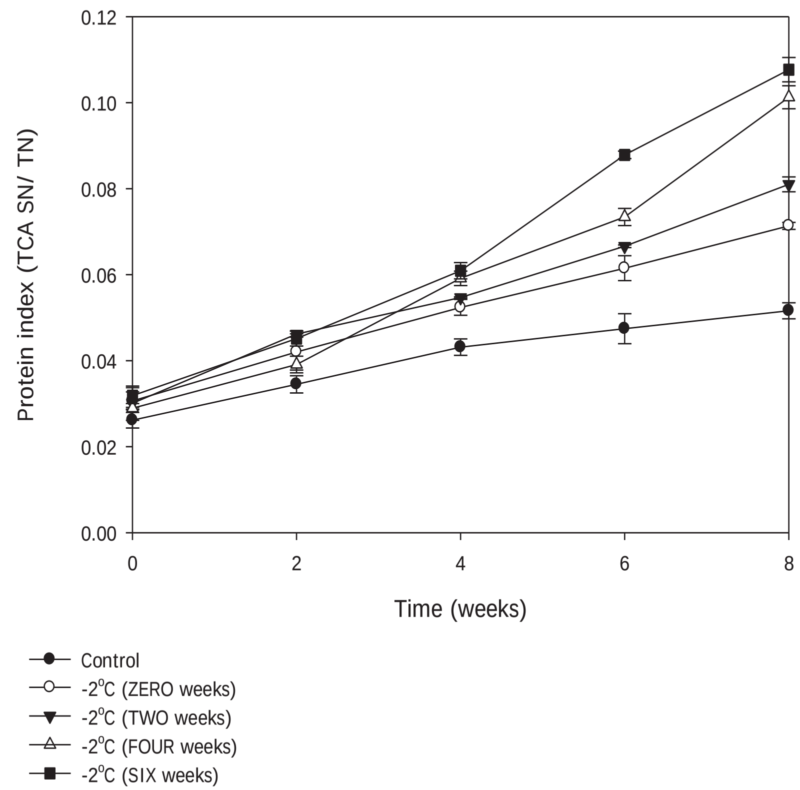
Each data point is representative of an average of duplicate samples ± standard error

Figure 6.26: Effect of -2°C storage on the pH 4.4 SN/ TN protein index of Camembert cheese following maturation at +4°C for eight week



Each data point is representative of an average of duplicate samples ± standard error

Figure 6.27: Effect of -2°C storage on the TCA SN/ TN protein index of Camembert cheese over 14 weeks



Each data point is representative of an average of duplicate samples ± standard error

Figure 6.28: Effect of -2°C storage on the TCA SN/ TN protein index of Camembert cheese following maturation at +4°C for eight weeks

Uniaxial compression testing

The results of the uniaxial compression tests of this study give an indication of the resistance of the cheese sample to deformation (Antoniou *et al.,* 2000, Van Hekken *et al.,* 2005). The structure of young curd in Camembert cheese is open and porous. As maturation proceeds with the decrease in moisture content, and increase in pH the cheese microstructure changes to become more compact where the para-casein strands and fat globules are more closely packed resulting in a softened cheese (Pierre *et al.,* 1999, Lucey *et al.,* 2003). From compression tests the work (N.mm) required to compress the samples was measured. The results found in this experiment show that the work required to compress all of the Camembert cheese samples to 80% of their original height decreased with storage and maturation time - see **Figure 6.29** and **Figure 6.30**. The work required to compress all of the samples that were matured at +4^{o}C for eight weeks following storage at -2^{o}C was less than the work required to compress the control sample over the same time period (1528.7±14.2 N.mm).

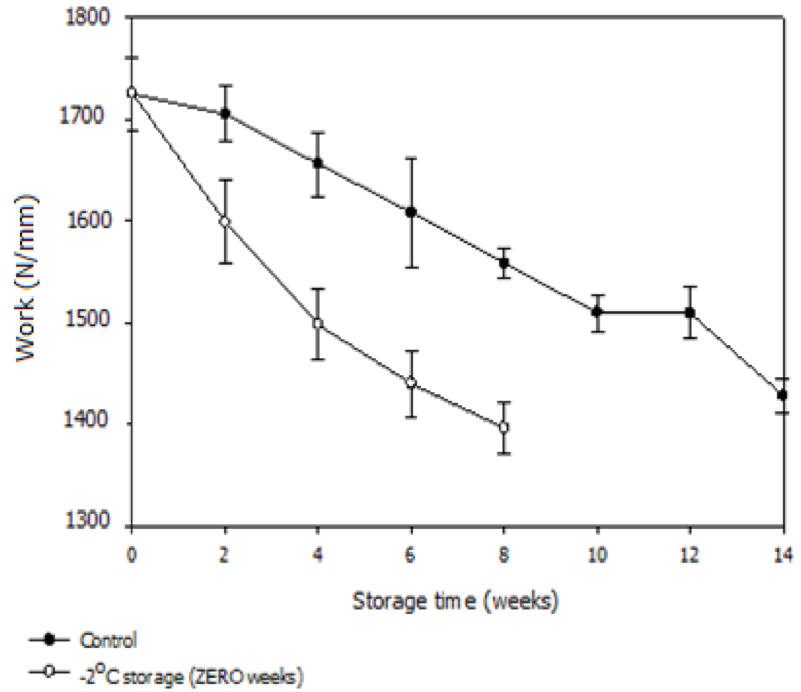
The structural integrity of Camembert cheese softens extensively throughout maturation at +4^{o}C, and the rate at which this happens increases with increased storage time at -2^{o}C (see **Table 6.25**). The rate (week^{-1}) is shown to almost double between the control sample (held at -2^{o}C) and the -2^{o}C storage (ZERO weeks) sample. Linear regression was used to determine the rate of softening during maturation over the eight week period.

Table 6.25: Rate of change in the uniaxial compression work (N.mm) of Camembert cheese throughout maturation at +4^{o}C: uniaxial compression (N.mm) = [rate] week^{-1} (p-value)

Treatment	Rate (week^{-1})	R^2 (%)
Control	-4215 (0.000)	98.1
-2^{o}C storage (ZERO weeks)	-8154 (0.004)	95.5
-2^{o}C storage (TWO weeks)	-10543 (0.001)	97.7
-2^{o}C storage (FOUR weeks)	-11281 (0.001)	98.4
-2^{o}C storage (SIX weeks)	-14380 (0.003)	96.5

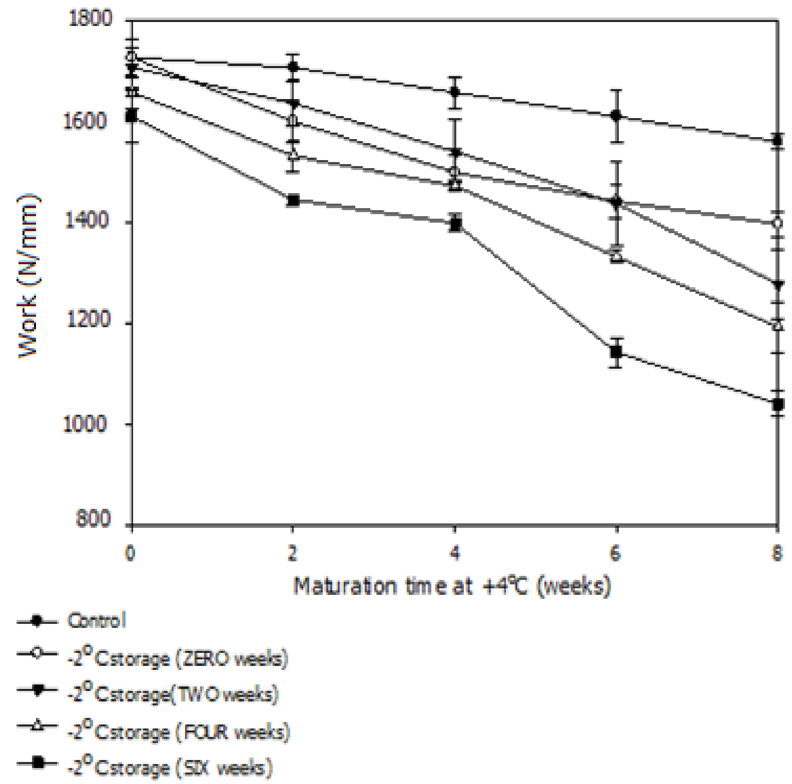
Linear regression was assumed for this analysis
Highlighted cells indicate significant effects (p-value < 0.010)

Maturation time at +4^{o}C, and total holding time were found to have a significant effect on the decrease in uniaxial compression force development (p-value < 0.010), however storage at -2^{o}C did not (**Table 6.19**).



Each data point is representative of an average of duplicate samples ± standard error

Figure 6.29: Effect of -2°C storage on the work required to compress the Camembert cheese samples to 80% of their original height over 14 weeks



Each data point is representative of an average of duplicate samples ± standard error

Figure 6.30: Effect of -2°C storage on the work required to compress the Camembert cheese samples to 80% of their original height following maturation at +4°C for eight weeks

Puncture testing

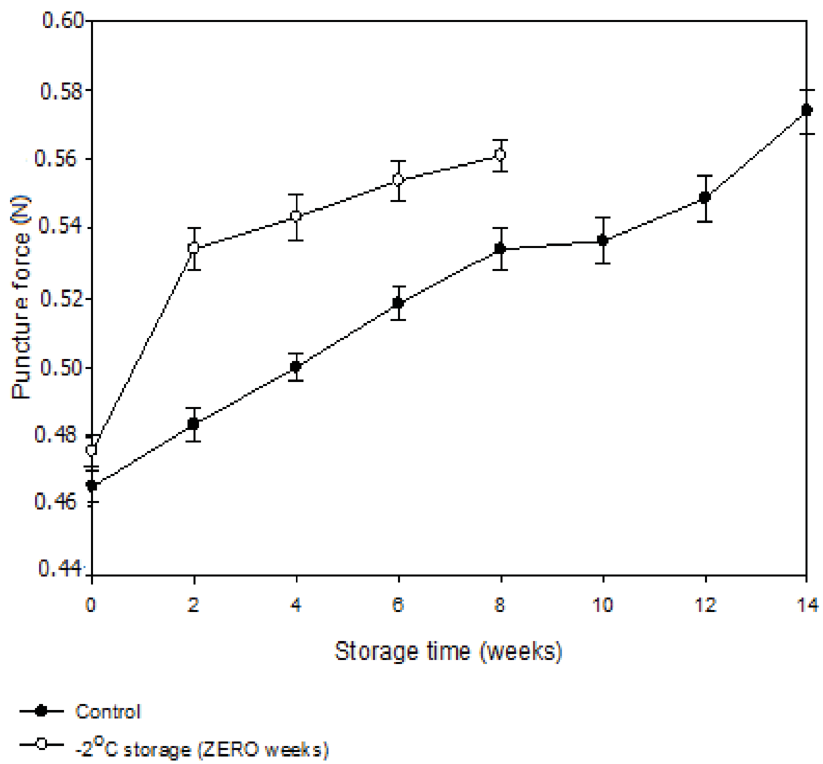
Puncture testing gives an indication of the resistant force required to rupture the external surface of the cheese sample, when the penetration depth is held constant (Bourne, 1966). This information can be useful as it has been suggested that the rind of Camembert cheese thickens throughout ripening due to the confounding effect of moisture loss and proteolysis (Bonaïti *et al.,* 2004). **Figure 6.31** and **Figure 6.32** shows an increasing force required to puncture the surface of the Camembert cheese samples with time, both with storage at -2°C and maturation at +4°C. The rate of thickening at the surface of Camembert cheese is considerably lower when the cheese was stored at -2°C (control sample), compared to the samples which underwent maturation at +4°C (-2°C storage (ZERO, TWO, FOUR and SIX weeks) – see **Table 6.26**. Linear regression was used to determine the rate of softening during maturation over the eight week period.

Table 6.26: Rate of change in the puncture force (N) of Camembert cheese throughout maturation at +4°C: puncture force (N) = [rate] week^{-1} (p-value)

Treatment	**Rate** (week^{-1})	$\mathbf{R^2}$ (%)
Control	1.44 (0.000)	97.9
-2°C storage (ZERO weeks)	1.91 (0.045)	78.7
-2°C storage (TWO weeks)	1.95 (0.012)	90.6
-2°C storage (FOUR weeks)	2.35 (0.000)	98.9
-2°C storage (SIX weeks)	2.15 (0.013)	90.4

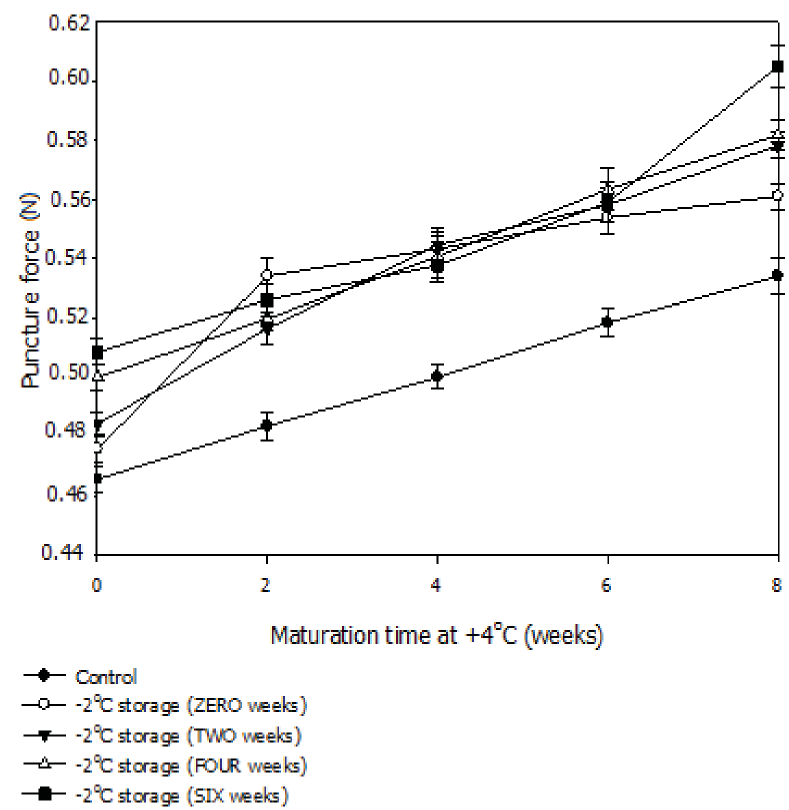
Linear regression was assumed for this analysis
Highlighted cells indicate significant effects (p-value < 0.010)

Results shown in **Table 6.19** show that maturation time and total holding time had a significant effect on the increase in the force required to puncture the surface of Camembert cheese (p-value < 0.010). Therefore these results imply that storage at -2°C for up to SIX weeks will not lead to significant rind thickening in the Camembert cheese samples compared to -2°C ZERO weeks.



Each data point is representative of an average of duplicate samples ± standard error

Figure 6.31: Effect of -2°C storage on peak puncture force over 14 weeks



Each data point is representative of an average of duplicate samples ± standard error

Figure 6.32: Effect of -2°C storage on the peak puncture force of Camembert cheese following maturation at +4°C for eight weeks

Correlations between compositional and textural analysis research

Correlation analysis between the Camembert cheese maturation properties (moisture content and pH), protein indices (pH 4.4 SN/ TN and TCA SN/ TN) and textural research (uniaxial compression and puncture force) was carried out to determine the strength of the relationship between two variables and to determine whether there is any evidence of a statistically significant association between them.

Table 6.27 shows that there is a statistically significant, strong correlation ($R > \pm 0.75$; p-value > 0.010) between the all of the maturation properties that were studied as part of this research. These findings support the literature whereby it has been extensively acknowledged that the ripening process of soft, mould ripened cheeses are induced by a sequential process of biochemical reactions (Smit *et al*., 2002).

Throughout maturation a gradient in the cheese pH is established between the outside and the centre of the cheese, which over time plateau's as the cheese matures. A strong negative correlation was observed between the inside pH and the uniaxial compression data (-0.931). This trend is supported by a range of authors. An increase in pH in Camembert cheese has been shown to be sufficient to soften the cheese texture; whereby the calcium ion's which act as the "cement" between the casein micelles solubilise as a result of the pH increase, leaving the cheese matrix susceptible to enzymatic degradation (Adda *et al.* 1982; Karahadian and Lindsay, 1987; Fox and Wallace, 1997; de Kruif, 1999; McSweeney, 2004).

A significant negative correlation was observed between the pH 4.4 SN/ TN and the TCA SN/ TN results and uniaxial compression (-0.918 and -0.957 respectively) – see **Table 6.27**; indicating that as the hydrolysis of casein progresses releasing nitrogenous compounds, softening the curd of the Camembert cheese samples. This trend has been well documented in the literature where several authors reported that proteolysis plays a significant role in the softening of Camembert throughout maturation (Adda *et al*., 1982, Fox, 1989, Fox and McSweeney, 1996).

Table 6.27: Correlations between the maturation properties of Camembert cheese

	Inside pH	**Outside pH**	**Moisture content**	**pH 4.4 SN/TN**	**TCA SN/TN**	**Uniaxial compression**
Outside pH	0.889 0.000					
Moisture content	-0.916 0.000	-0.940 0.000				
pH 4.4 SN/TN	0.923 0.000	0.844 0.000	-0.874 0.000			
TCA SN/TN	0.930 0.000	0.814 0.000	0.890 0.000	0.950 0.000		
Uniaxial compression	-0.931 0.000	-0.821 0.000	0.887 0.000	-0.918 0.000	-0.957 0.000	
Puncture test	0.890 0.000	0.880 0.000	-0.935 0.000	0.926 0.000	0.939 0.000	-0.905 0.000

Pearsons Correlation
P-value
Highlighted cells indicate significant correlations (p-value > 0.010)

A strong relationship (0.950) was observed between the pH 4.4 SN/ TN results and the TCA SN/TN results. This correlation is consistent with the literature whereby Ardö (1999) reported that there is an overlap in the compounds which are extracted between the pH 4.4 SN/ TN and the TCA SN/ TN, where the pH 4.4 SN/ TN fraction contains all peptides of all molecular weights and the TCA SN/ TN contains small peptides and amino acids.

Enzymes which are secreted by the surface moulds during cheese ripening have been shown to facilitate proteolysis at a range of pH's. These are:

- Carboxy-peptidases (optium pH=3.5-6.0);
- Aspartyl-proteinases (optimum pH =5.0);
- Amino-peptidases (optimum pH 5.0-8.5);
- Metallo-proteinases (optimum pH=6.0).

(Trieu-Cuot and Grippon, 1982; Lenoir, 1984)

This progression of pH and the hydrolysis of caseins (proteolysis) are in alignment with the correlations observed in **Table 6.27** between the pH results (inside and outside pH) and the two protein indices results (pH 4.4 SN/ TN and TCA SN/ TN).

Bonaïti *et al.* (2004) showed that Camembert cheese samples lost moisture over time, resulting in the thickening of the cheese under-rind. This same relationship was observed in between the moisture content (%) and puncture test (N) results (correlation = -0.935). Packaging optimisation has been shown to be an effective way to reduce the extent of moisture loss and rind thickening over time by adding a hydrosorbent layer and micro-perforations to the internal surface of Camembert cheese packaging (Mathlouthi *et al.,* 1994).

6.4.2 Consumer Research

Consumer evaluation tests can be used to give an indication of the acceptability and/ or perceived preference of certain product characteristics, using current or potential users of a product (Meilgaard *et al.,* 2007). In this study, demographic, as well as attribute acceptability and intensity; overall acceptability and "likelihood of purchase" information was obtained.

Acceptability data

Samples were presented to the subjects using an incomplete block design (six samples, four were presented to each subject) to reduce any variation that may be caused by the order that the samples are judged. Each consumer was asked to rate each sample with their perceived acceptability in terms of *appearance, aroma, bitter flavour, texture, creamy texture* and *overall liking.* The results shown in **Figure 6.33** and **Table 6.28** indicated that each of the six samples were not significantly different in terms of *aroma, flavour, bitter flavour, texture creamy texture* and *overall liking* (indicated by the p-values being greater than 0.010). A significant judge effect in the evaluation of *aroma* was noted; and therefore any true similarity of differences in the perception of this attribute may be masked by this effect.

Table 6.28: Table of significant effects; acceptability response of the Camembert cheese samples

Attribute	Judge	Sample
Appearance	0.101	0.003
Aroma	0.000	0.360
Flavour	0.805	0.035
Bitter Flavour	0.139	0.058
Texture	0.116	0.171
Creamy Texture	0.040	0.762
Overall Liking	0.441	0.051

Highlighted figures indicate significant effects (p-value < 0.010)

Table 6.28 also shows that there was a significant difference between the *appearance* of the samples (shown by the p-value being less than 0.010). Statistical analysis on this data (one way ANOVA; appearance vs sample at 99% confidence interval – see **Appendix: from page 244**) showed that the most significant difference was found between the Control sample; and the -2^{o}C storage (ZERO weeks) and (FOUR weeks) samples. Consumer comments of these samples relates particularly to a "grey", "yellow" or "brown" "unappealing" colour – see **Appendix: from page 248**. According to Meilgaard *et al.* (2007) the perception of *appearance* attributes can be influenced by such characteristics as the size and shape of the sample; and the textural appearance.

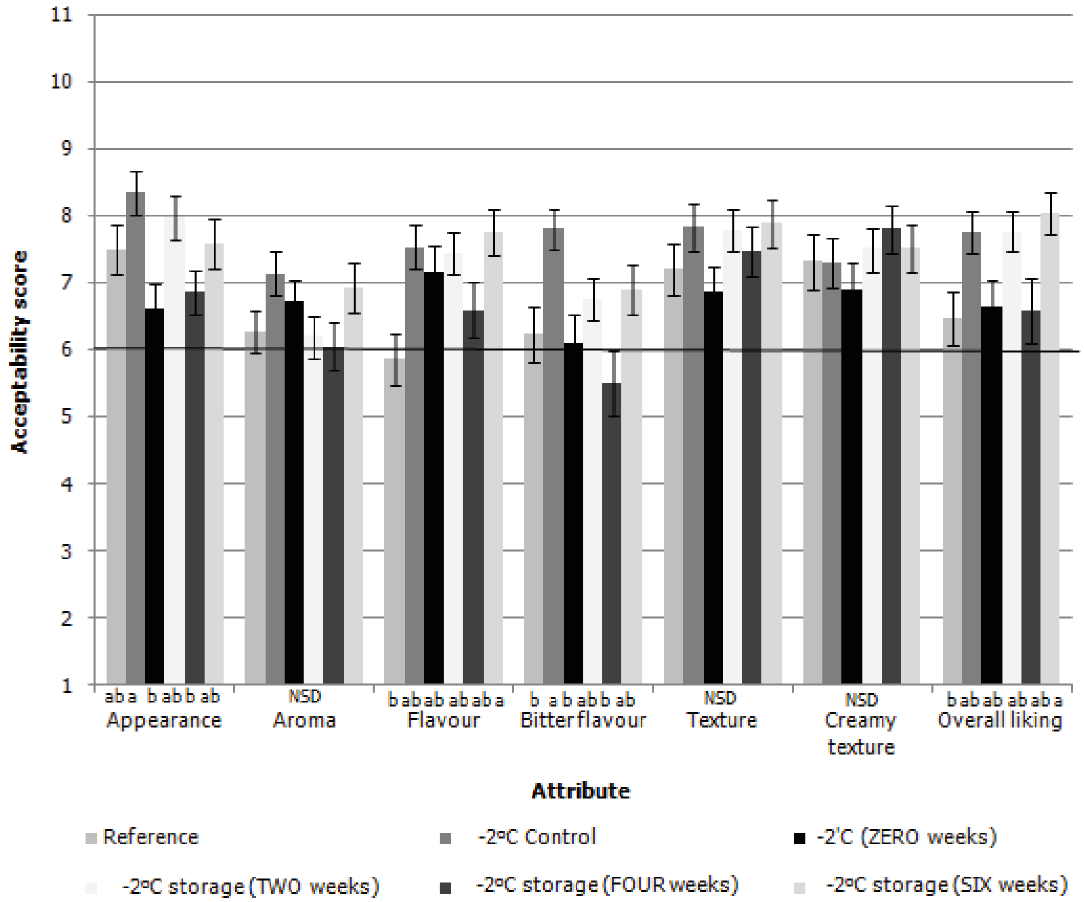


Figure 6.33: Consumers ranking for the acceptability of six Camembert cheese samples where Reference = fresh sample

1 = dislike very much
Line at the "6 acceptability score" = midpoint
11 = like very much

In acceptance testing, the results can be used to give an indication of preference (like very much to dislike very much), where a higher acceptability score suggests greater preference between samples (Meilgaard *et al.,* 2007). **Figure 6.33** shows that consumers ranked the acceptability of the cheese samples on the "like very much" side of the scale for *appearance, aroma, texture, creamy texture* and *overall liking.* However the *flavour* of the reference sample, and the *bitter flavour* of the -2^{o}C storage (FOUR weeks) cheese were ranked on the "dislike very much" side of the scale.

Regression analysis was carried out on the data to determine the key attributes which drive the overall acceptability of the Camembert cheese samples based on consumers response scores – see **Appendix: from page 247**. When *overall* *acceptability* was modelled against those attributes which were found to be statistically significant at the 95% level of confidence (*appearance, flavour* and *bitter flavour*), it was found that an accurate response could be generated 70.2% of the time – see **Equation 3** below.

$$\text{Overall Liking} = -0.105 + 0.539\ \text{Flavour} + 0.230\ \text{Bitter Flavour} + 0.267\ \text{Appearance} \qquad \textbf{Equation 3}$$

Intensity response data

Consumers were asked to rate each sample on their perceived intensity of the *aroma, flavour, bitter flavour* and *creamy texture* i.e "just right" scale. The intensity aspect of sensory analysis is a way for consumers to express the degree to which each attribute is present in relation to an individual's perceived preference (or rejection), and therefore allows the identification of potential shortcomings of the products being tested (Meilgaard *et al.,* 2007). These results are shown in **Figure 6.34**.

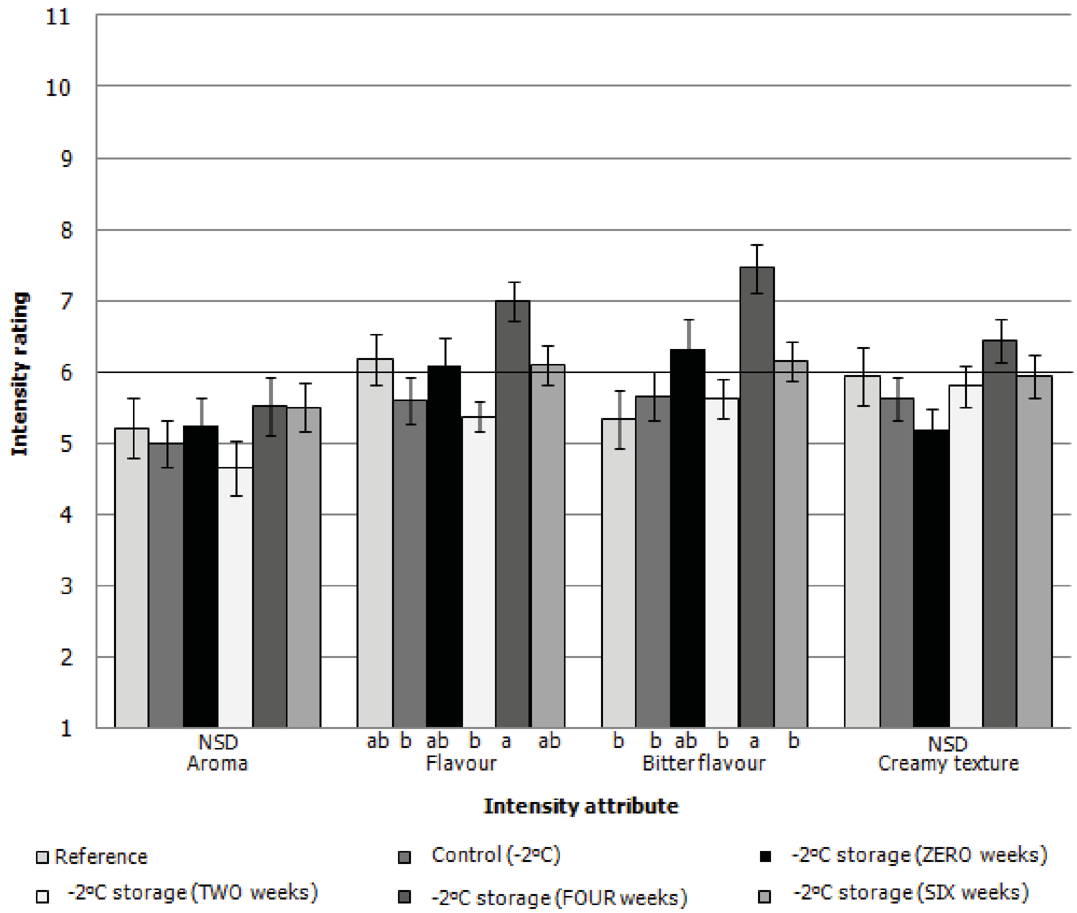


Figure 6.34: Consumers ranking for the intensity of six Camembert cheese samples

1 = too weak for me
6 = just right
11 = too strong for me

Figure 6.34 shows that consumers rated most samples for all attributes at an intensity rating of 5-6 which is around the "just right" area of the intensity scale. Therefore this indicates that the samples for these attributes were typical of what a consumer would expect in Camembert cheese.

The *intensity of flavour* was found to be on the "too weak for me" side of the scale for the -2^{o}C storage (TWO weeks) sample, and on the "too strong for me" side of the scale for the -2^{o}C storage (FOUR weeks) sample – see **Figure 6.34**. Both samples were found to be similarly judged with respect to the *intensity of aroma* and *intensity of bitter flavour* respectively. Meilgaard *et al.,* (2007) indicates that the flavour attribute is closely influenced by the aromatic/ volatile compounds which are released through mastication, and certain chemical irritants which have a negative influence on our overall perception of flavour. Therefore, it can be assumed that the factors which influenced the "too weak for me" response with respect to the *intensity of aroma* attribute in the -2°C storage (TWO weeks) may also influence consumer's response with respect to the *intensity of flavour*.

Natural chemical irritants, such as ammonia, have been found to influence the perception of bitter notes in Camembert cheese and therefore can confound responses in sensory analysis, especially within an untrained sensory panel, or in a consumer test (Meilgaard *et al.,* 2007). From the consumer comments (see **Appendix: from page 248**) a total of 13 comments were made relating directly to the *bitter flavour* of the -2°C storage (FOUR weeks) sample, therefore the shortcomings of this sample may be attributed to the extent of proteolysis (hydrolysis of small hydrophobic peptides originating from both α_{s1} -, and β-casein) which induces the development of the bitter flavour in Camembert cheese.

According to Meilgaard *et al.* (2007), the reliability of results in relation to intensity data is largely dependent on the type of scale that is used and an individual's ability to consistently use the scale the same way throughout the evaluation procedure. When conducting sensory analysis with consumers who are not trained sensory panellists, it is some-what expected that there will be a lack of consistency in the judging of each attribute because each individual will use the scale differently. This is shown by the significant judge effects with respect to the *intensity of aroma, flavour* and *creamy texture* (see **Table 6.29**); therefore any true similarity or differences in the perceived intensity of these attributes is out-weighed by this significant judge effect. However, because of the bi-polar nature of just-about-right scales, data that is normally distributed around the centre of the scale (ie: the "just about right" category) are indicative of an optimised level of that particular attribute (Meilgaard *et al.,* 2007).

Table 6.29: Table of significant effects; intensity response of Camembert cheese samples

Attribute	Judge	Sample
Intensity of aroma	0.001	0.383
Intensity of flavour	0.010	0.013
Intensity of bitter flavour	0.199	0.003
Intensity of creamy texture	0.000	0.149

Highlighted figures indicate significant effects (p-value < 0.010)

Preferred sample

Further indication of consumer acceptance of the samples is shown through the *"likelihood of purchase"* question – see **Figure 6.35**.

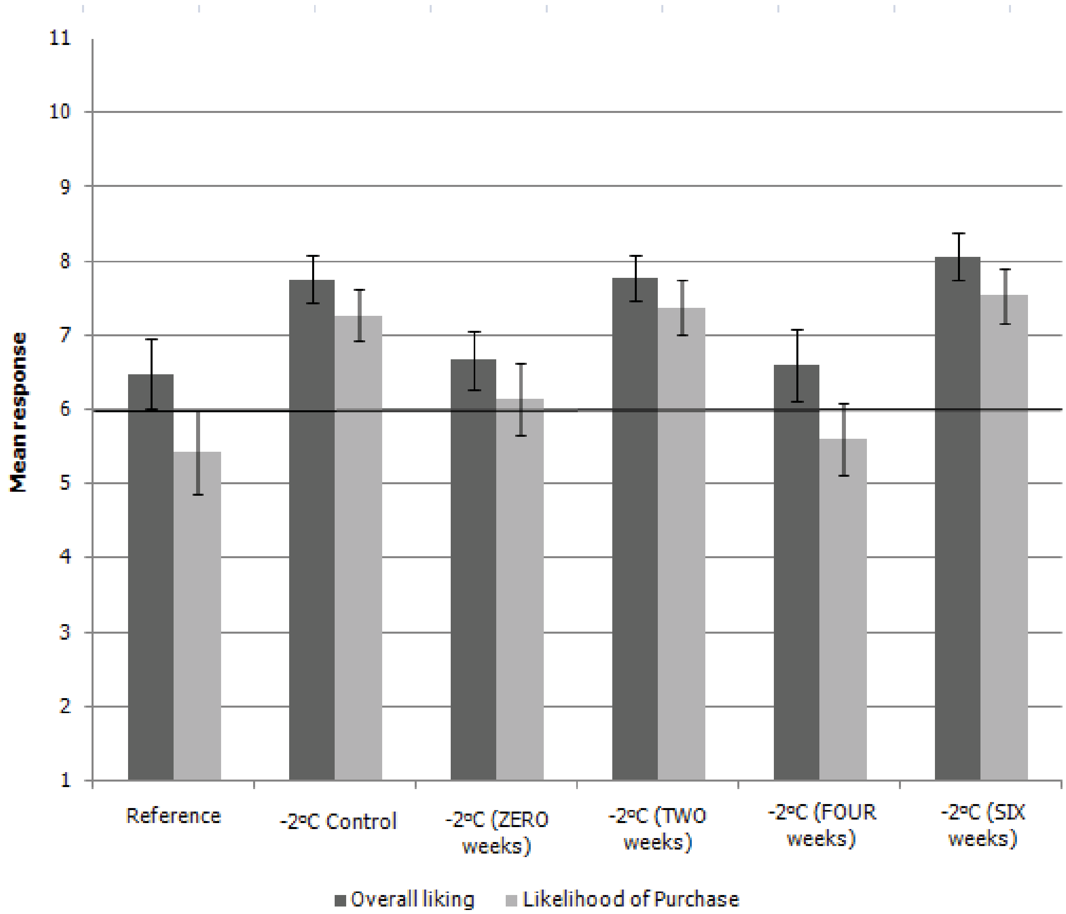


Figure 6.35: Mean response for *overall liking* and *likelihood of purchase* for each sample

Figure 6.35 shows that although the mean *overall liking* score for each sample is on the "like" side of the scale, the consumers may not be likely to purchase the Reference, or -2°C storage (FOUR weeks) samples. This indicates that although consumers may "like" the samples, they are not necessarily likely to purchase the samples.

The number of consumer responses for each sample is shown **Figure 6.36**.

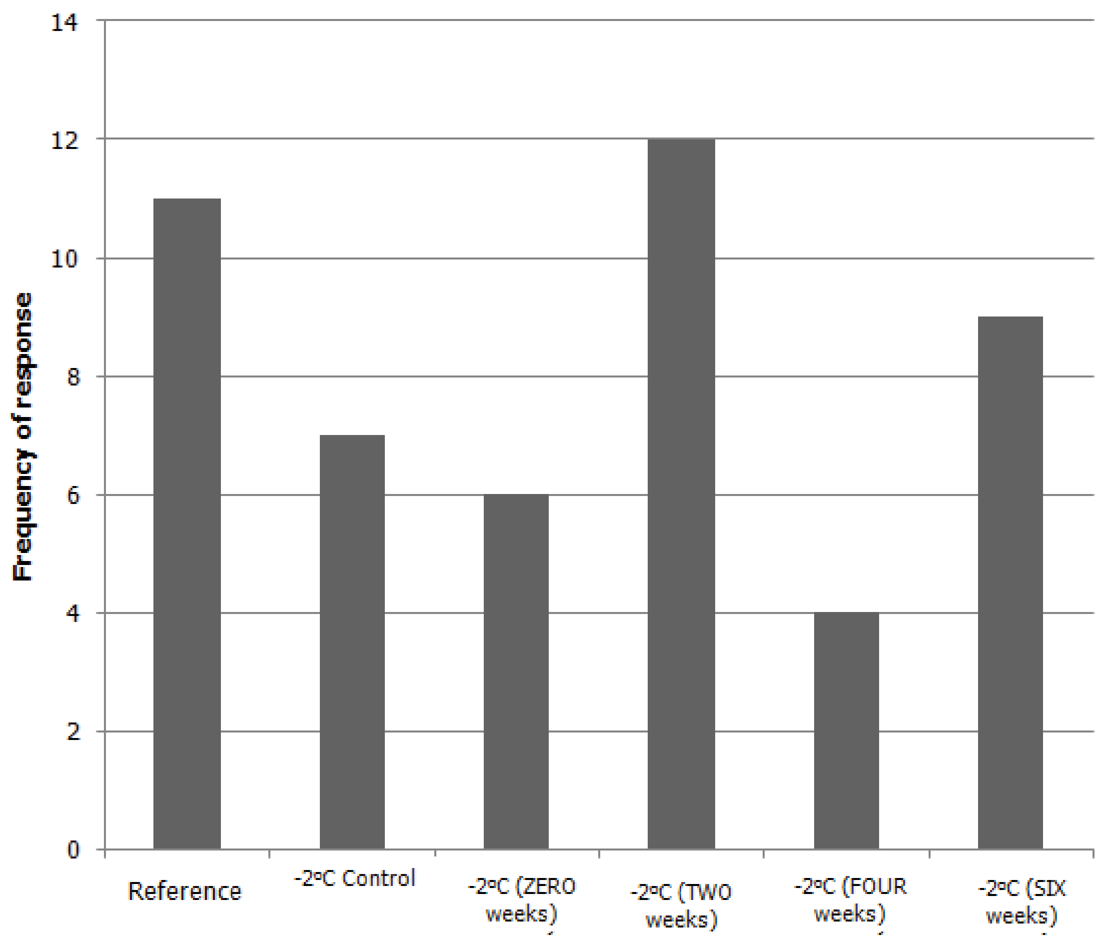


Figure 6.36: Frequency of "preferred sample" response

According to **Figure 6.36** the most preferred sample was -2°C storage (TWO weeks), however it was difficult to draw an accurate conclusion as to the exact attributes that have influenced the acceptability of these samples, as the cheese used for each treatment was sourced from a different batches, there may have been slight differences in the milk composition, manufacturing process, initial microbiological load and hence they would have had a subsequent influence of these factors on the organoleptic properties of the cheese.

The samples with the highest mean response in terms of *overall liking* and *likelihood of purchase* were the Control sample; and the -2°C storage (TWO and SIX weeks) samples. Throughout the consumer testing the -2°C storage (FOUR weeks) sample consistently gave anomalous results in comparison to the other samples, this may have been due to batch variation from this reverse storage trial.

6.5 Outcomes of Stage TWO trials

From these trials it was found that:

1. Storing Camembert cheese at -2°C for up to SIX weeks, followed by maturation at +4°C for eight weeks successfully controlled the rate of maturation for all maturation properties that were investigated (*moisture content, pH of the centre* and *outside portions, pH 4.4 SN/ TN, TCA SN / TN, uniaxial compression* and *puncture testing*); whereby storage at -2°C slowed down the changes in these properties such that increasing the shelf life of Camembert cheese is possible;
2. Consumers did not find a significant difference between the samples that were presented in terms of *aroma, flavour, bitter flavour, texture creamy texture* and *overall liking;*
3. Consumers showed "overall liking" and "preference" for samples which had been treated with -2°C storage (TWO weeks) and -2°C storage (SIX weeks). The -2°C storage (FOUR weeks) sample consistently gave anomalous results in comparison to the other samples, which may have been due to batch variation from this reverse storage trial.

7.0 Quantitative Descriptive Analysis (QDA) trials

7.1 Background

These trials were carried out simultaneously with the Stage TWO Trials (**Chapter 6.0**). Quantitative Descriptive Analysis was carried out to monitor the organoleptic changes throughout storage of Camembert cheese samples at -2^{o}C and maturation at +4^{o}C.

7.2 Research objectives

The objectives of the current work were to:

1. Train a reproducible sensory panel for QDA;
2. Monitor the organoleptic changes in Camembert cheese throughout maturation.

7.3 Methodology

7.3.1 Panel training

Nine judges (three females and nine males, aged between 20 and 30 years) were selected and screened for colour blindness, aroma and flavour acuity using ranking/ rating tests for intensity (see **Appendix: from page 258** for detail of the screening procedure used and the results of panel screening tests). Judges were trained over a five week period, consisting of 12 one to two hour sessions:

Session One - generation of descriptors

TRAINING OBJECTIVES

The objectives of the current work were to:

1. Develop a list of descriptors based on the appearance, texture (tactile and mouthfeel), aroma and flavour of two camembert cheese samples;
2. Establish a standardised evaluation procedure.

METHOD

Three-digit random numbers were generated and assigned to each sample to ensure anonymity between the products. Panellists were presented with two samples:

Sample	Sample description	Date of manufacture	Storage temperature	Factory of manufacture
1	Bouton d'or Camembert 125g	26.04.08	4^oC	Puhoi Valley Cheese Company Ltd
2	Bouton d'or Camembert 125g	01.03.08	Sample stored at -2^oC for 4 weeks then ≈ 5 weeks at 4^oC	Puhoi Valley Cheese Company Ltd

The samples were removed from storage two-hours prior to the commencement of the training session to allow the cheeses to warm to room temperature (as per recommended usage instructions). Samples were presented to the panellists simultaneously. The descriptive data from the product profile evaluation forms was collated and recorded in a "round-table" group discussion.

RESULTS

From the descriptors that were generated, the terms that were most commonly used among the entire panel were used in the evaluation form for Session Two.

A generic evaluation procedure was also discussed and was taken into consideration when developing the evaluation form for Session Two.

OUTCOMES

The attributes and evaluation procedure that were carried forward to Session Two were:

Appearance
Mould/ external surface:
Discolouration of mould
Browning throughout mould
Whiteness of mould
Overall mould coverage

Looking at a cross-section of the cheese sample:
Dryness of crust
Shiny/ oily/ glossy/ waxy
Evenness of curd (between the rind and centre)

Aroma
The Aroma of the cheese is to be evaluated by smelling the mould of the sample.

Nutty
Dirty/ stale/ cardboard
Ammonia
Fresh mushrooms
Buttery
Fruity

Tactile Texture
Mould coverage/ external surface:
Leathery
Velvety

Curd:
Greasy
Sticky
Waxy

Cross-sectional compression:
Spongy
Springy
Rubbery
Firm
Soft

Mouthfeel Texture
Rind crunch
Gluey/ pasty
Creamy
Oily
Rubbery
Smooth
Sticky

Flavour
Buttery
Salty
Grassy
Bitter
Creamy
Acidic/ sour

Session Two – descriptor consensus

TRAINING OBJECTIVES

The objectives of the current work were to:

1. Refine the list of attributes by eliminating any redundant attributes;
2. Add further detail to the evaluation procedure.

METHOD

Three-digit random numbers were generated and assigned to each sample to ensure anonymity between the products. Panellists were presented with two samples:

Sample	Sample description	Date of manufacture	Storage temperature	Factory of manufacture
1	Bouton d'or Camembert 125g	26.04.08	$4^{o}C$	Puhoi Valley Cheese Company Ltd
2	Bouton d'or Camembert 125g	01.03.08	Sample stored at $-2^{o}C$ for 4 weeks then ≈ 5 weeks at $4^{o}C$	Puhoi Valley Cheese Company Ltd

The samples were removed from storage two-hours prior to the commencement of the training session to allow the cheeses to warm to room temperature (as per recommended usage instructions).

Samples were presented to the panellists individually and were asked to judge each sample using the descriptors generated from Session One on an 11-point ordinal scale (see example below):

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

NOT [*attribute*] Moderate VERY [*attribute*]

Following the evaluation a "round-table" group discussion was held to discuss the evaluation procedure.

RESULTS

From the data obtained, a Pearsons Correlation test was carried out using Minitab-version 15 –see **Table 7.30**.

Table 7.30: Pearson correlation of attributes used for Session Two training

<table>
<tr><th>Correlated attributes</th><th>Correlation</th><th>Justification</th><th>Decision</th></tr>
<tr><td>Whiteness of mould was inversely correlated with browning throughout the mould</td><td>-0.910
0.000</td><td>The panel related to the term whiteness of the mould better than browning throughout the mould (lower standard deviation for both samples)
<table>
<tr><th>Attribute</th><th colspan="2">Standard deviation</th></tr>
<tr><th></th><th>Sample 1</th><th>Sample 2</th></tr>
<tr><td>Whiteness of the mould</td><td>1.581</td><td>1.302</td></tr>
<tr><td>Browning of the mould</td><td>1.832</td><td>2.475</td></tr>
</table></td><td>Kept whiteness of the mould</td></tr>
<tr><td>Dryness of the crust was positively correlated with shinny/ oily/ glossy (of the curd)</td><td>0.795
0.000</td><td>Dryness of the crust will correlate better with puncture test measurements than shinny/ oily/ glossy</td><td>Kept dryness of the crust</td></tr>
<tr><td>Firmness was inversely correlated with Softness</td><td>-0.836
0.000</td><td>The panel related to the term Firmness better than softness (more consistent standard deviation between both samples)
<table>
<tr><th>Attribute</th><th colspan="2">Standard deviation</th></tr>
<tr><th></th><th>Sample 1</th><th>Sample 2</th></tr>
<tr><td>Firmness</td><td>1.685</td><td>1.246</td></tr>
<tr><td>Softness</td><td>2.121</td><td>1.847</td></tr>
</table></td><td>Kept firmness</td></tr>
<tr><td>Firmness was inversely correlated with shinny/ oily/ glossy</td><td>-0.844
0.000</td><td>Shinny/ oily/ glossy already eliminated</td><td>Kept firmness</td></tr>
<tr><td>Rind crunch was positively correlated with shinny/ oily/ glossy</td><td>0.786
0.000</td><td>Shinny/ oily/ glossy already eliminated; AND rind crunch will relate to puncture test measurements</td><td>Kept rind crunch</td></tr>
</table>

<table>
<tr><th>Correlated attributes</th><th>Correlation</th><th>Justification</th><th>Decision</th></tr>
<tr><td>Creamy curd texture was positively correlated with dryness of the crust</td><td>0.792
0.000</td><td>The panel related better to the term creamy curd texture than dryness of the crust (lower standard deviation for both samples)however dryness of the crust can be correlated with textural measurements
<table>
<tr><th>Attribute</th><th colspan="2">Standard deviation</th></tr>
<tr><td></td><td>Sample 1</td><td>Sample 2</td></tr>
<tr><td>Creamy</td><td>0.641</td><td>0.926</td></tr>
<tr><td>Dryness of the crust</td><td>0.701</td><td>1.309</td></tr>
</table></td><td>Kept both terms creamy curd texture and dryness of the crust</td></tr>
<tr><td>Stickiness was positively correlated with greasy mouthfeel</td><td>0.781
0.000</td><td>Stickiness will be easier to correlate with textural measurements than greasy mouthfeel</td><td>Kept stickiness</td></tr>
<tr><td>Smoothness of the curd (mouthfeel) is inversely correlated with rubbery</td><td>-0.747
0.000</td><td>The panel related better to the term smoothness than rubbery (lower standard deviation for both samples)
<table>
<tr><th>Attribute</th><th colspan="2">Standard deviation</th></tr>
<tr><td></td><td>Sample 1</td><td>Sample 2</td></tr>
<tr><td>Smoothness</td><td>0.641</td><td>1.281</td></tr>
<tr><td>Rubbery</td><td>1.768</td><td>1.496</td></tr>
</table></td><td>Kept smoothness</td></tr>
<tr><td>Creamy flavour was positively correlated with buttery/ diacetyl flavour</td><td>0.763
0.001</td><td>The panel related better to the term buttery/ diacetyl flavour better than creamy flavour (lower standard deviation for both samples)
<table>
<tr><th>Attribute</th><th colspan="2">Standard deviation</th></tr>
<tr><td></td><td>Sample 1</td><td>Sample 2</td></tr>
<tr><td>Buttery/ diacetyl flavour</td><td>1.877</td><td>1.642</td></tr>
<tr><td>Creamy flavour</td><td>1.309</td><td>2.193</td></tr>
</table></td><td>Kept buttery/ diactyl flavour</td></tr>
</table>

Correlated attributes	Correlation	Justification	Decision
Bitter flavour was inversely correlated with *Acidic/ sour flavour*	-0.828 0.000	The panel related better to the term *Acidic/ sour flavour* better than *bitter flavour* (lower standard deviation for both samples) **Attribute** — **Standard deviation** (Sample 1, Sample 2) *Bitter flavour*: 1.237, 1.376 *Acidic/ sour flavour*: 0.926, 1.243	Kept *Acidic/ sour flavour*

Pearson correlation
p-value

Other terms to be kept in include:

<table>
<tr><th>Attribute</th><th>Justification</th></tr>
<tr><td>Springiness of the curd</td><td>The springiness of the curd will change throughout the shelf life of the product. This is shown by the means of the respective samples being separated by more than 2 units for the springiness of the curd attribute:
<table>
<tr><th rowspan="2">Attribute</th><th colspan="2">Mean score</th></tr>
<tr><th>Sample 1</th><th>Sample 2</th></tr>
<tr><td>Springiness of the curd</td><td>8.125</td><td>4.500</td></tr>
</table>
This can also be quantified using uniaxial compression measurements.</td></tr>
<tr><td>Mushroom aroma
Dirty/ stale/ cardboard aroma
Ammonia aroma</td><td>The intensity of these three attributes will change throughout the shelf life of the product. This is shown by the means of the respective samples being separated by more than 2 units for each attribute:
<table>
<tr><th rowspan="2">Attribute</th><th colspan="2">Mean score</th></tr>
<tr><th>Sample 1</th><th>Sample 2</th></tr>
<tr><td>Mushroom aroma</td><td>7.000</td><td>4.000</td></tr>
<tr><td>Dirty/ stale/ cardboard aroma</td><td>5.250</td><td>8.125</td></tr>
<tr><td>Ammonia aroma</td><td>3.500</td><td>7.250</td></tr>
</table>
</td></tr>
</table>

Discussion with the panel, in regard to the evaluation procedure, revealed that the mouthfeel attributes would be best evaluated by presenting the panellists with a sample that did not have the rind still on the cheese.

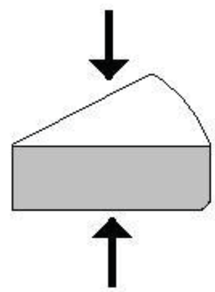
OUTCOMES

The evaluation procedure and attributes, as per the revised descriptors, to be taken forward to Session Three is shown in **Figure 7.37**.

Appearance
Panellists to evaluate the *whiteness of the mould* and *dryness of the crust* of the cheese

Aroma
The *Mushroom, dirty/ stale/ cardboard* and *ammonia* aroma is to be evaluated by smelling the mould of the sample

Tactile Texture
Springy, and *firmness* should be evaluated by compressing a cross section of sample between the index finger and thumb



Mouthfeel Texture
Rind crunch is to be evaluated on the first initial bite of a cross section of the cheese

Smooth, *creamy and stickiness* should be evaluated by chewing the sample and evenly distributing the curd (rind removed) of the sample over the tongue

Flavour
The *butter/ diacetyl* and *acidic/ sour* flavour should be evaluated by chewing the sample and distributing evenly over the tongue to ensure that the cheese is exposed to all of the taste receptors.

Figure 7.37: Schematic of the tasting evaluation procedure to be used in the evaluation of Camembert cheese

Session Three – introduction of reference standards and development of definitions

TRAINING OBJECTIVES

The objectives of the current work were to:

1. Ensure that the panel is consistent in grading each attribute by the introduction of reference standards that the panel can use to relate specific attributes with;
2. Write formal definitions for each attribute.

METHODOLOGY

Three-digit random numbers were generated and assigned to each sample to ensure anonymity between the products. Panellists were presented with two samples:

Sample	Sample description	Date of manufacture	Storage temperature	Factory of manufacture
1	Bouton d'or Camembert 125g	≈0.7.05.08	4°C	Puhoi Valley Cheese Company Ltd
2	Bouton d'or Camembert 125g	01.03.08	Sample stored at -2°C for 4 weeks then ≈ 6 weeks at 4°C	Puhoi Valley Cheese Company Ltd

The samples were removed from storage two-hours prior to the commencement of the training session to allow the cheeses to warm to room temperature (as per recommended usage instructions).

The panel was presented with the following reference standards prior to the presentation of the samples (see **Table 7.31**).

Table 7.31: Reference standards used in Quantitative Descriptive Analysis

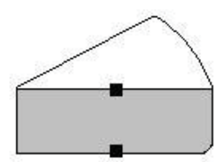
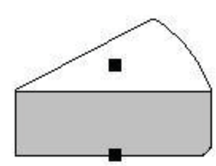
Attribute	#	Reference standard	Supplier
Whiteness of the mould	1	The panel were shown two extreme cheeses. A new cheese with a "snowy" white mould, and a cheese from -10°C; 4 week storage with severe tanning. It was explained to the panel that they would not see a cheese as tanned as the -10°C; 4 week storage sample, but that it was extent of this "discolouration" that was to be evaluated.	N/A
Mushroom Aroma	2	Fresh field mushrooms (as recommended by Drake *et al.*, 2005)	White button mushrooms; Meadow Mushrooms (Christchurch New Zealand)
Dirty/ stale/ cardboard Aroma	3	Wet cardboard (as recommended by Civille and Lyon, 1996) This reference standard was made by cutting the cardboard into $10cm^2$ squares, soaking it in 100mL of tap water, and putting the cardboard and water in an air oven at 100°C for 10 minutes prior to the session.	N/A
Ammonia Aroma	4	Ammonia solution (0.25% in distilled water) (as recommended by Delahunty and Drake, 2004)	Scharlau Ammonia, reagent grade (25%); Global Science and Technology Ltd (Auckland, New Zealand)
Creamy Mouthfeel	5	Marscapone (as recommended by Drake *et al.*, 2005)	Bouton D'or Marscapone; Puhoi Valley Cheese Company Ltd
Stickiness of the curd	6	Smooth peanut butter (recommended by panellist)	Pams smooth peanut butter; Pam's products Ltd (Auckland, New Zealand)
Buttery Flavour	7	Fresh N.Z. butter (as recommended by Civille and Lyon, 1996)	Mainland traditional salted butter; Fonterra Brands (NZ) Ltd (Auckland, New Zealand)
Acidic/ sour Flavour	8	0.1% citric acid in distilled water (as recommended by Civille and Lyon, 1996)	Hansells citric acid; Hansells food group, Auckland, New Zealand)
Bitterness	9	0.1% (w/v) caffeine dissolved in distilled water (as recommended by Civille and Lyon, 1996)	Scharlau Caffiene, anhydrous extra pure; Global science and technology Ltd (Auckland, New Zealand)

Samples were presented to the panellists individually and were asked to judge each sample using the descriptors generated from Session Two on an 11-point ordinal scale in a "round-table" discussion.

RESULTS

Following discussion with the panel, the following definitions were agreed upon for the judging of each of the attributes (see **Table 7.32**).

Table 7.32: Trained panel descriptors and definitions

Attribute	Definition
Whiteness of the mould	Degree of colour change (not white to very white)
Dryness of the crust	The "crustiness" of the cheese immediately under the rind; in comparison the centre of the cheese
Mushroom aroma	The intensity of the fresh field mushroom aroma in the mould of the cheese (reference: fresh field mushrooms)
Dirty/ stale/ cardboard aroma	The intensity of the dusty/ stale/ cardboard aroma in the mould of the cheese (reference: wet cardboard)
Ammonia aroma	The intensity of the ammonia aroma in the mould of the cheese (reference: 0.25% ammonia dissolved in distilled water)
Springiness; tactile texture	The degree to which the cheese returns to its original height following a 25% compression. The compression is to be carried out using the thumb and index finger, on the cross-sectional edge of the cheese, half way along the length of the sample: 
Firmness; tactile texture	The force required to compress the cheese between the thumb and index finger/ resistance of the cheese to deformation when compressed between the thumb and index finger: 
Rind Crunch	The difference in texture between the rind of the cheese and the curd from the first bite into a cross-section of the cheese
Acidic/ sour flavour	The intensity of the acidity/ sourness in the cheese (reference: 0.1% citric acid in distilled water)
Smoothness: mouthfeel	The degree to which the cheese fractures and grains form when of the cheese when mushed over the tongue following initial mastication (2-5 chews)
Stickiness; mouthfeel	The adhesiveness/ pastiness of the sample against the palate and around the teeth throughout mastication (suggested reference to be introduced next session: smooth peanut butter)
Creamy; mouthfeel	The creaminess of the curd over the tongue following mastication

The mean scores were determined using the descriptive statistics function in Minitab version 15.

Table 7.33: Table of mean scores for the judging of two samples of approximately 2 and 6 weeks old

Attribute	Mean scores	
	Sample 1 Sample = ≈2 weeks old at time of judging	**Sample 2** Sample = ≈6 weeks old at time of judging
Whiteness of the mould	9.000	3.429
Dryness of the crust	2.143	8.714
Mushroom aroma	7.286	3.000
Dirty/ stale/ cardboard aroma	4.714	8.000
Ammonia aroma	3.286	8.143
Springiness; tactile texture	7.714	2.429
Firmness; tactile texture	8.286	2.857
Rind Crunch	2.143	8.286
Fresh buttery flavour	4.571	6.286
Acidic/ sour flavour	9.286	2.571
Smoothness: mouthfeel	7.571	3.000
Stickiness; mouthfeel	7.857	4.286
Creamy; mouthfeel	3.571	9.000

Table 7.33 shows that the panellists were scoring both samples more than 2 units apart for each attribute. This indicates that they are able to find significant differences in the intensity of each attribute between the two samples.

OUTCOMES

The panellists were able to relate to the reference standards that were used, and were able to score the two samples more than 2 units apart for the intensity of each attribute.

For Session Four Pams smooth peanut butter was to be introduced as a reference standard for *stickiness*.

Session Four - reproducibility of panellists on descriptor perception

TRAINING OBJECTIVE

The objective of the current work was to ensure that the panellists were able to score Sample 2 within 1.5 units of the results obtained from **Table 7.33** in Session Three.

METHODOLOGY

A three-digit random numbers were generated and assigned to the sample to ensure anonymity between the products. Panellists were presented with one sample:

Sample	Sample description	Date of manufacture	Storage temperature	Factory of manufacture
1	Bouton d'or Camembert 125g	01.03.08	Sample stored at -2°C for 4 weeks then ≈ 6 weeks at 4°C	Puhoi Valley Cheese Company Ltd

The sample was removed from storage two-hours prior to the commencement of the training session to allow the cheeses to warm to room temperature (as per recommended usage instructions).

The panel was presented with the first eight reference standards presented in **Table 7.31**.

RESULTS

The mean scores for Sample 2 from Session Three and Session Four were determined using the descriptive statistics function in Minitab version 15.

Table 7.34: Table of mean scores for the judging of two samples, of approximately 6 weeks old

Attribute	Mean scores	
	Sample 2-Session Three Sample = ≈6 weeks old at time of judging	**Sample 2-Session Four** Sample = ≈6 weeks old at time of judging
Whiteness of the mould	3.429	3.857
Dryness of the crust	8.714	9.286
Mushroom aroma	3.000	4.286
Dirty/ stale/ cardboard aroma	8.000	7.000
Ammonia aroma	8.143	6.714
Springiness; tactile texture	2.429	3.286
Firmness; tactile texture	2.857	3.429
Rind Crunch	8.286	8.857
Fresh buttery flavour	6.286	5.857
Acidic/ sour flavour	2.571	3.286
Smoothness: mouthfeel	3.000	3.857
Stickiness; mouthfeel	4.286	4.571
Creamy; mouthfeel	9.000	9.000

Table 7.34 shows that the panellists were scoring both samples of the same age within 1.5 units of each other. This indicates that the panellists are consistently identifying similarities in the intensity of attributes.

OUTCOMES

Panellists were successfully able to score the two samples, of approximately six weeks old, within 1.5 units.

The *ammonia aroma* attribute was scored with a 1.429 unit differential indicating that the panellists were successfully able to score the two samples within 1.5 units of each other. For Session Five the *ammonia aroma* reference standard was presented to the panel prior to evaluation.

Session Five – let's get reproducible

TRAINING OBJECTIVES

The objectives of the current work were to:

1. Standardise the scoring of each attribute within the panel to reduce variation between the panellists;
2. Re-introduce the reference standard for *ammonia aroma.*

METHODOLOGY

Three-digit random numbers were generated and assigned to each sample to ensure anonymity between the products. Panellists were presented with two samples in the Massey University sensory booths:

Sample	Sample description	Date of manufacture	Storage temperature	Factory of manufacture
1	Bouton d'or Camembert 125g	≈14.05.08	4°C (two weeks maturation)	Puhoi Valley Cheese Company Ltd
2	Bouton d'or Camembert 125g	01.03.08	Sample stored at -2°C for 4 weeks then ≈ 6 weeks at 4°C	Puhoi Valley Cheese Company Ltd

The samples were removed from storage two-hours prior to the commencement of the training session to allow the cheeses to warm to room temperature (as per recommended usage instructions).

The panel was presented with reference standard number 4 as shown in **Table 7.31**.

RESULTS

Results were analysed in Minitab version 15 using the General Linear Model (GLM) function to determine the significant effects between the judges and samples.

Table 7.35: Table of significant effects between two samples for Session Five

Attribute	Judge Effect	Sample Effect
Whiteness of the mould	0.774	0.000
Dryness of the crust	0.092	0.000
Mushroom aroma	0.990	0.099
Dirty/ stale/ cardboard aroma	0.966	0.041
Ammonia aroma	0.944	0.191
Springiness; tactile	0.633	0.000
Firmness; tactile	0.810	0.000
Rind crunch	0.637	0.000
Fresh buttery flavour	0.643	0.122
Acidity/ sourness flavour	0.969	0.221
Stickiness of the curd; mouthfeel	0.874	0.180
Creamy mouthfeel	0.601	0.001
Smoothness of the curd	0.814	0.000

Highlighted cells indicate significant effects (p-value < 0.010)

Table 7.35 indicates that the judges were collectively (no significant judge effect, p-value > 0.010) finding significant differences in the intensity of *whiteness of the mould, dryness of the crust, springiness, firmness, rind crunch, creamy mouthfeel and smoothness of the curd* (shown by the significant sample effect, p-value < 0.010), between the two samples of approximately two weeks and six weeks age.

OUTCOMES

Panellists were collectively able to find differences in the intensity of some attributes of samples which are approximately one week and six weeks in age.

For Session Six further training was required for *mushroom aroma, ammonia aroma, fresh buttery flavour, acidity/ sourness* and *stickiness of the curd* to ensure that the panel was able to find significant differences in the intensity of these attributes between the two samples.

Session Six – let's get reproducible

TRAINING OBJECTIVES

The objectives of the current work were to:

1. Standardise the scoring of each attribute within the panel to reduce variation between the panellists;
2. Re-introduce the reference standards for *mushroom aroma, ammonia aroma, fresh buttery flavour, acidity/ sourness* and *stickiness of the curd.*

METHODOLOGY

Three-digit random numbers were generated and assigned to each sample to ensure anonymity between the products. Panellists were presented with two samples in the Massey University sensory booths:

Sample	Sample description	Date of manufacture	Storage temperature	Factory of manufacture
1	Bouton d'or Camembert 125g	≈24.05.08	4°C	Puhoi Valley Cheese Company Ltd
2	Bouton d'or Camembert 125g	01.03.08	Sample stored at -2°C for 4 weeks then ≈ 7 weeks at 4°C	Puhoi Valley Cheese Company Ltd

The samples were removed from storage two-hours prior to the commencement of the training session to allow the cheeses to warm to room temperature (as per recommended usage instructions).

The panel was presented with reference standard number 2, 4, 6, 7 and 8 as shown in **Table 7.31**.

RESULTS

Results were analysed in Minitab version 15 using the GLM function to determine the significant effects between the judges and samples.

Table 7.36: Table of significant effects between two samples for Session Six

Attribute	Judge Effect	Sample Effect
Whiteness of the mould	0.210	0.000
Dryness of the crust	0.752	0.000
Mushroom aroma	0.998	0.034
Dirty/ stale/ cardboard aroma	0.308	0.002
Ammonia aroma	0.694	0.006
Springiness; tactile	0.415	0.001
Firmness; tactile	0.997	0.034
Rind crunch	0.432	0.000
Fresh buttery flavour	0.520	1.000
Acidity/ sourness flavour	0.149	0.002
Stickiness of the curd; mouthfeel	0.999	0.416
Creamy mouthfeel	0.676	0.026
Smoothness of the curd	0.919	0.004

Highlighted cells indicate significant effects (p-value < 0.010)

Table 7.36 indicates that judges were collectively finding significant differences in the intensity of *whiteness of the mould, dryness of the crust, mushroom aroma, dirty/ stale/ cardboard aroma, ammonia aroma, springiness, rind crunch, acidity/ sourness flavour* and *smoothness of the curd* (shown by the significant sample effect, p-value < 0.010), between the two samples of approximately one week and seven weeks age.

As a result of the insignificant sample effects for both *fresh buttery flavour* and *stickiness of the curd* the mean scoring of these two attributes was checked to ensure that the panel were still able to find a difference in the two samples (were they scoring more than 2 units apart) –see **Table 7.37**.

Table 7.37: Check to see the panellists mean scores for *Fresh buttery flavour* and *Stickiness of the curd*

Attribute	Mean score	
	Sample 1	Sample 2
Fresh buttery flavour	6.857	6.429
Stickiness of the curd	7.286	4.286

Table 7.37 indicates that the panel were unable to find a significant difference in the *Fresh buttery flavour* between the two samples, therefore it was eliminated. However, they were still able to discriminate between the *stickiness of the curd* in the two samples that were presented.

OUTCOMES

Panellists were collectively able to find significant differences in the intensity of most attributes for two samples of approximately one week and seven weeks in age.

For Session Seven:

1. *Fresh buttery flavour* was eliminated as a term
2. Further training was required for on *Stickiness of the curd* to ensure that the panel was able to find significant differences in the intensity of these attributes between the two samples.

Session Seven – let's get reproducible

TRAINING OBJECTIVES

The objectives of the current work were to:

1. Standardise the scoring of each attribute within the panel to reduce variation between the panellists;
2. Re-introduce the reference standard for *stickiness of the curd.*

METHODOLOGY

Three-digit random numbers were generated and assigned to each sample to ensure anonymity between the products. Panellists were presented with two samples in the Massey University sensory booths:

Sample	Sample Description	Date of Manufacture	Storage Temperature	Factory of Manufacture
1	Bouton d'or Camembert 125g	≈24.05.08	$4^{o}C$	Puhoi Valley Cheese Company Ltd
2	Bouton d'or Camembert 125g	01.03.08	Sample stored at $-2^{o}C$ for 4 weeks then ≈ 7 weeks at $4^{o}C$	Puhoi Valley Cheese Company Ltd

The samples were removed from storage two-hours prior to the commencement of the training session to allow the cheeses to warm to room temperature (as per recommended usage instructions).

The panel was presented with reference standard number 6 as presented in **Table 7.31**.

RESULTS

Results were analysed in Minitab version 15 using the GLM function to determine the significant effects between the judges and samples.

Table 7.38: Table of significant effects between two samples for Session Seven

Attribute	Judge Effect	Sample Effect
Whiteness of Mould	0.974	0.000
Dryness of Crust	0.655	0.000
Mushroom Aroma	0.358	0.000
Dirty/ Stale/ Cardboard Aroma	0.685	0.005
Ammonia Aroma	0.088	0.000
Springiness	0.806	0.000
Firmness	0.030	0.000
Rind Crunch	0.412	0.000
Acidic/ Sour Flavour	0.420	0.000
Stickiness of the curd	0.905	0.017
Creamy Mouthfeel	0.958	0.001
Smoothness	0.323	0.000

Highlighted cells indicate significant effects (p-value < 0.010)

Table 7.38 indicates that judges were collectively finding significant differences in the intensity for all of the attributes, except for the *stickiness of the curd* attribute (shown by the significant sample effect, p-value < 0.010), between the two samples of approximately two weeks and seven weeks age.

Upon discussion with the panel it was decided to re-introduce the *bitter flavour* attribute (eliminated in Session Two) as they noted a difference in the bitterness of the two samples that were being presented each session. Therefore

OUTCOMES

Panellists were collectively able to find significant differences in the intensity of all attributes for two samples of approximately two weeks and seven weeks in age

For Session Eight:

1. Judge 1 required further training on the evaluation of the *Firmness* attribute
2. Re-introduced *Bitterness flavour* as an attribute

Session Eight – let's get reproducible

TRAINING OBJECTIVES

The objectives of the current work were to:

1. Standardise the scoring of each attribute within the panel to reduce variation between the panellists;
2. Test the panellists ability to consistently quantify similarities or small changes between blind duplicate samples;
3. Re-train Judge 1 on the definition of the *firmness* attribute;
4. Re-introduce the *bitter flavour* attribute. If the panel were able to collectively score the two samples more than 2 units apart then this attribute was to remain in the sensory evaluation form for testing.

METHODOLOGY

Three-digit random numbers were generated and assigned to each sample to ensure anonymity between the products. Panellists were presented with two samples in the Massey University sensory booths:

Sample	Sample Description	Date of Manufacture	Storage Temperature	Factory of Manufacture
1	Bouton d'or Camembert 125g	≈24.05.08	4^oC (three weeks maturation)	Puhoi Valley Cheese Company Ltd
2	Bouton d'or Camembert 125g	≈26.04.08	4^oC (six weeks maturation)	Puhoi Valley Cheese Company Ltd

The samples were removed from storage two-hours prior to the commencement of the training session to allow the cheeses to warm to room temperature (as per recommended usage instructions).

A blind duplicate of Sample 1 was presented as the third sample to ensure that the panellists are able to consistently score the two samples the same.

The panel was presented with reference standard number 9 (as shown in **Table 7.31**) and definition number 7 (as shown in **Table 7.32**).

RESULTS

The mean scores were determined using the descriptive statistics function in Minitab version 15.

Table 7.39: Check to see the panellists mean scores for *bitter flavour*

Attribute	**Mean score**	
	Sample 1	Sample 2
Bitter flavour	3.063	8.625

Table 7.39 indicates that the panellists were collectively able to identify a difference in the intensity of the *bitter flavour* between the two samples by the mean scores being more than 2 units apart; therefore this remained an attribute for all consecutive evaluations.

Results were analysed in Minitab version 15 using the GLM function to determine the significant effects between the judges and samples.

Table 7.40: Table showing effects between three samples for Session Eight

Attribute	**Judge**	**Sample**
Whiteness of the mould	0.439	0.000
Dryness of the crust	0.438	0.000
Mushroom aroma	0.646	0.000
Dirty/ stale/ cardboard aroma	0.468	0.000
Ammonia aroma	0.010	0.000
Springiness; tactile	0.717	0.000
Firmness; tactile	0.969	0.009
Rind crunch	0.789	0.000
Bitter Flavour	0.001	0.000
Acidity/ sourness flavour	0.669	0.000
Stickiness of the curd; mouthfeel	0.996	0.425
Creamy mouthfeel	0.930	0.029
Smoothness of the curd	0.600	0.001

Highlighted cells indicate significant effects (p-value < 0.010)

According to Minitab version 15, Judge 1 was an unusual observation for the judging of *ammonia aroma* and *bitterness*.

Table 7.40 indicates that judges are collectively finding significant differences in the intensity of all of the attributes, except *stickiness of the curd* and *creamy mouthfeel* (shown by the significant sample effect, p-value < 0.010), between the two samples of approximately three weeks and six weeks age.

Table 7.41: Table showing effects between the duplicate samples for Session Eight

Attribute	Judge	Sample
Whiteness of the mould	0.562	0.388
Dryness of the crust	0.453	0.174
Mushroom aroma	0.212	0.790
Dirty/ stale/ cardboard aroma	0.526	0.573
Ammonia aroma	0.001	0.170
Springiness; tactile	0.425	0.135
Firmness; tactile	0.023	0.102
Rind crunch	0.546	0.142
Bitter Flavour	0.017	1.000
Acidity/ sourness flavour	0.770	0.191
Stickiness of the curd; mouthfeel	0.500	0.605
Creamy mouthfeel	0.877	0.454
Smoothness of the curd	0.812	0.361

Highlighted cells indicate significant effects (p-value < 0.010)

Table 7.41 shows that the panellists were collectively finding no significant difference in the intensity of all of the attributes (shown by the p-values > 0.010) between the duplicate samples, however according to Minitab version 15 Judge 5 was an unusual observation for the judging of *ammonia aroma.*

OUTCOMES

Panellists were collectively able to find significant differences in the intensity of all attributes except *stickiness of the curd* and *creamy mouthfeel* for two samples of approximately three weeks and six weeks in age, and no significant difference in the intensity of all attributes for the duplicate samples was found.

For Session Nine:

1. Judge 1 required further training on the evaluation of the *ammonia aroma* and *bitterness* attributes;
2. Judge 6 requires further training on the evaluation of *ammonia aroma, firmness* and *bitter flavour.*

Session Nine – let's get reproducible

TRAINING OBJECTIVE

The objective of the current work was to standardise the scoring of each attribute within the panel to reduce variation between the panellists

METHODOLOGY

Three-digit random numbers were generated and assigned to each sample to ensure anonymity between the products. Panellists were presented with three samples in the Massey University sensory booths:

Sample	Sample description	Date of manufacture	Storage temperature	Factory of manufacture
1	Bouton d'or Camembert 125g	≈04.06.08	4°C (one week maturation)	Puhoi Valley Cheese Company Ltd
2	Bouton d'or Camembert 125g	≈24.05.08	4°C (three weeks maturation)	Puhoi Valley Cheese Company Ltd
3	Bouton d'or Camembert 125g	≈26.04.08	4°C (six week maturation)	Puhoi Valley Cheese Company Ltd

The samples were removed from storage two-hours prior to the commencement of the training session to allow the cheeses to warm to room temperature (as per recommended usage instructions).

The panel was presented with reference standard numbers 4 and 9 as shown in **Table 7.31**.

RESULTS

Results were analysed in Minitab version 15 using the GLM function to determine the significant effects between the judges and samples.

Table 7.42: Table showing effects between three samples for Session Nine

Attribute	Judge	Sample
Whiteness of the mould	0.401	0.000
Dryness of the crust	0.331	0.003
Mushroom aroma	0.297	0.001
Dirty/ stale/ cardboard aroma	0.368	0.003
Ammonia aroma	0.216	0.000
Springiness; tactile	0.170	0.005
Firmness; tactile	0.143	0.000
Rind crunch	0.361	0.000
Bitter Flavour	0.136	0.000
Acidity/ sourness flavour	0.132	0.000
Stickiness of the curd; mouthfeel	0.517	0.000
Creamy mouthfeel	0.948	0.002
Smoothness of the curd	0.735	0.000

Highlighted cells indicate significant effects (p-value < 0.010)

Error! Reference source not found. shows that the panellists were collectively inding a significant difference in the intensity of all of the attributes (shown by the significant sample effect, p-value < 0.010) between the three samples of approximately one, three and six weeks age, respectively.

OUTCOMES

Panellists were collectively finding a significant difference in the intensity of attributes in samples ranging from one to six weeks of age.

Session Ten – let's get reproducible

TRAINING OBJECTIVES

The objectives of the current work were to:

1. Standardise the scoring of each attribute within the panel to reduce variation between the panellists;
2. Test the panellist's ability to consistently quantify similarities or small changes between blind duplicate samples.

METHODOLOGY

Three-digit random numbers were generated and assigned to each sample to ensure anonymity between the products. Panellists were presented with two samples in the Massey University sensory booths:

Sample	Sample description	Date of manufacture	Storage temperature	Factory of manufacture
1	Bouton d'or Camembert 125g	≈04.06.08	4^oC (two weeks maturation)	Puhoi Valley Cheese Company Ltd
2	Bouton d'or Camembert 125g	≈24.05.08	4^oC (four weeks maturation)	Puhoi Valley Cheese Company Ltd

The samples were removed from storage two-hours prior to the commencement of the training session to allow the cheeses to warm to room temperature (as per recommended usage instructions).

A blind duplicate of Sample 1 was presented as the third sample to ensure that the panellists were able to consistently score the two samples the same.

RESULTS

Results were analysed in Minitab version 15 using the GLM function to determine the significant effects between the judges and samples.

Table 7.43: Table showing effects between three samples for Session Ten

Attribute	Judge	Sample
Whiteness of the mould	0.045	0.000
Dryness of the crust	0.014	0.000
Mushroom aroma	0.008	0.000
Dirty/ stale/ cardboard aroma	0.808	0.000
Ammonia aroma	0.147	0.000
Springiness; tactile	0.320	0.000
Firmness; tactile	0.689	0.000
Rind crunch	0.687	0.000
Bitter Flavour	0.463	0.000
Acidity/ sourness flavour	0.081	0.000
Stickiness of the curd; mouthfeel	0.096	0.000
Creamy mouthfeel	0.875	0.000
Smoothness of the curd	0.139	0.000

Highlighted cells indicate significant effects (p-value < 0.010)

According to Minitab version 15 Judge 1 was found to be an unusual observation for *mushroom aroma.*

Table 7.43 shows that the panellists were collectively finding a significant difference in the intensity of all of the attributes (shown by the significant sample effect, p-value < 0.010) between the two samples of approximately two and four weeks age respectively.

Table 7.44: Table showing effects between the duplicate samples for Session Ten

Attribute	Judge	Sample
Whiteness of the mould	0.109	1.000
Dryness of the crust	0.002	0.080
Mus-hroom aroma	0.003	0.402
Dirty/ stale/ cardboard aroma	0.003	0.685
Ammonia aroma	0.009	0.685
Springiness; tactile	0.157	0.170
Firmness; tactile	0.007	0.020
Rind crunch	0.459	0.217
Bitter Flavour	0.081	0.197
Acidity/ sourness flavour	0.003	0.732
Stickiness of the curd; mouthfeel	0.134	0.567
Creamy mouthfeel	0.500	0.685
Smoothness of the curd	0.282	0.108

Highlighted cells indicate significant effects (p-value < 0.010)Error! Reference source not ound. shows that the panellists were collectively finding no significant difference in the intensity of all of the attributes, except *dryness of the crust* and *firmness* (shown by the p-values > 0.05) between the duplicate samples, however according to Minitab version 15:

1. Judge 2 was found to give an unusual observation for *dryness of the crust* and *mushroom aroma;*
2. Judge 4 gave an unusual observation for *Dirty/ stale/ cardboard aroma;*
3. Judge 9 gave an unusual observation for *Ammonia aroma;*
4. Judge 5 gave an unusual observation for *firmness;*
5. Judge 7 gave an unusual observation for *Acidity/ sourness flavour.*

OUTCOMES

For Session Ten the panel were reminded of the definitions for each attribute and were re-familiarised with each of the reference standards.

Session Eleven – let's get reproducible

TRAINING OBJECTIVE

The objective of the current work was to re-introduce the formal definitions and reference standards to ensure that the panel was consistent in grading each attribute

METHODOLOGY

This was a relaxed training session where the panel were presented with all nine reference standards (as shown in **Table 7.31)** and the definitions (as shown in **Table 7.32**), and a "round-table" discussion was held to ensure that the panel were happy and comfortable with the tasting procedure.

Session Twelve – let's get reproducible

TRAINING OBJECTIVE

The objective of the current work was to standardise the scoring of each attribute within the panel to reduce variation between the panellists

METHODOLOGY

Three-digit random numbers were generated and assigned to each sample to ensure anonymity between the products. Panellists were presented with four samples in the Massey University sensory booths:

Sample	Sample description	Date of manufacture	Storage temperature	Factory of manufacture
1	Bouton d'or Camembert 125g	≈24.05.08	4^{o}C (one week maturation)	Puhoi Valley Cheese Company Ltd
2	Bouton d'or Camembert 125g	≈14.05.08	4^{o}C (two weeks maturation	Puhoi Valley Cheese Company Ltd
3	Bouton d'or Camembert 125g	≈04.06.08	4^{o}C (four weeks maturation)	Puhoi Valley Cheese Company Ltd
4	Bouton d'or Camembert 125g	≈11.06.08	4^{o}C (six weeks maturatrion)	Puhoi Valley Cheese Company Ltd

The samples were removed from storage two-hours prior to the commencement of the training session to allow the cheeses to warm to room temperature (as per recommended usage instructions).

RESULTS

Results were analysed in Minitab version 15 using the GLM function to determine the significant effects between the judges and samples.

Table 7.45: Table showing effects between three samples for Session Twelve

Attribute	Judge	Sample
Whiteness of the mould	0.694	0.000
Dryness of the crust	0.534	0.000
Mushroom aroma	0.148	0.000
Dirty/ stale/ cardboard aroma	0.087	0.000
Ammonia aroma	0.673	0.000
Springiness; tactile	0.603	0.000
Firmness; tactile	0.158	0.000
Rind crunch	0.596	0.000
Bitter Flavour	0.221	0.002
Acidity/ sourness flavour	0.186	0.000
Stickiness of the curd; mouthfeel	0.138	0.004
Creamy mouthfeel	0.136	0.000
Smoothness of the curd	0.250	0.000

Highlighted cells indicate significant effects (p-value < 0.010)

Table 7.45 shows that the panellists were collectively finding a significant difference in the intensity of all of the attributes (shown by the significant sample effect, p-value < 0.010) between the four samples of approximately one, two, four and six weeks age, respectively.

OUTCOMES

Panellists were collectively finding a significant difference in the intensity of attributes in samples ranging from one to six weeks of age.

A finalised copy of the evaluation form that was used from session seven and for all Quantitative Descriptive Analysis testing is shown in **Appendix: from page 260**. The reproducibility and corrective actions (steps taken to ensure accuracy of the results) for each of the QDA testing sessions is shown in **Appendix: from page 264**.

7.3.2 Product testing

TESTING OBJECTIVE

The objective of the current work was to monitor the organoleptic changes in Camembert cheese throughout maturation using a trained sensory panel.

METHODOLOGY

All sensory testing evaluations were carried out using the sensory analysis booths at Massey University. The booths provide a completely controlled environment (temperature set at 20^{o}C and a uniform light source) and ensured independent results between panellists. The panellists were assigned to specific booths for the duration of the trained panel trial, and were presented with Bouton d'or Camembert 125g (product code: 569044; batch code: 0203E) samples that were picked up from Puhoi Valley Cheese Ltd. on 30 June, 2008.

Three-digit random numbers were generated and assigned to each sample, including a blind duplicate sample to check for reproducibility and a fresh reference sample (picked up fresh from Puhoi Valley Cheese Company Ltd. prior to each session); to ensure anonymity between the products. The samples were presented to each panellist in a randomised order for each session. A total of eight evaluations were carried out at a standardised time and day over a 14 week period (see **Figure 7.38**).

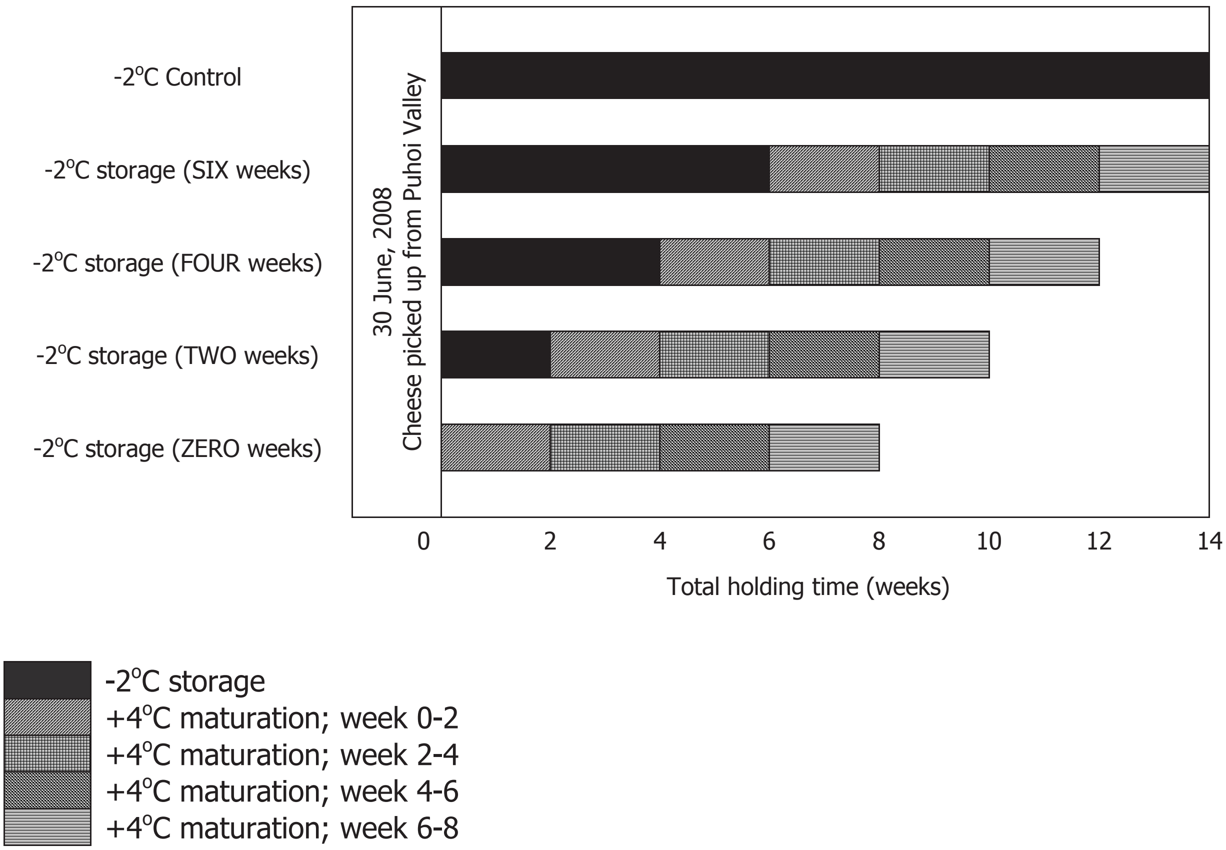


Figure 7.38: Schematic of storage regime of Quantitative Descriptive Analysis trials

The samples were removed from storage two-hours prior to the commencement of the training session to allow the cheeses to warm to room temperature (≈20°C; as per recommended usage instructions).

7.4 Results and discussion

The change in the development profile of each attribute throughout storage at -2°C (samples held at -2°C for 14 weeks) and the -2°C storage (ZERO weeks) (samples held at +4°C for eight weeks) are represented as mean scores across all nine trained panellists in **Figure 7.39** to **Figure 7.63** Similarly the development profile of each attribute following -2°C storage (ZERO, TWO, FOUR, SIX weeks)) are represented as mean scores across all nine trained panellists in **Figure 7.40** to **Figure 7.64**.

All testing was carried out two-weekly from the first day of storage. The following appearance, texture (tactile), aroma and flavour texture (mouthfeel) attributes were monitored.

Attribute	Page
Appearance	From page 150
Whiteness of the mould	
Dryness of the crust	
Aroma	From page 154
Mushroom aroma	
Dirty/ stale/ cardboard aroma	
Ammonia aroma	
Texture (tactile)	From page 160
Springiness; tactile	
Firmness; tactile	
Rind crunch	
Flavour	From page 165
Bitter Flavour	
Acidity/ sourness flavour	
Texture (mouthfeel)	From page 169
Stickiness of the curd; mouthfeel	
Creamy mouthfeel	
Smoothness of the curd	

Results were analysed in Minitab version 15 using the GLM function to determine the significant effects of the attribute development when Camembert cheese samples were stored at -2±1°C for up to SIX weeks. Storage time, maturation time of the cheese at +4±1°C, and total holding time (up to 14 weeks; storage time at ZERO, TWO, FOUR or SIX weeks + maturation time for eight weeks) of the cheese were modelled against each attribute – **Table 7.46**.

Table 7.46: Table of significant effects (ANOVA)

Attribute	Storage time at -2°C	Maturation time at +4°C	Total holding time
Whiteness of the mould	0.320	0.000	0.000
Dryness of the crust	0.773	0.000	0.001
Mushroom aroma	0.509	0.000	0.000
Dirty/ stale/ cardboard aroma	0.677	0.000	0.001
Ammonia aroma	0.646	0.000	0.001
Springiness	0.647	0.000	0.000
Firmness	0.308	0.000	0.000
Rind crunch	0.748	0.000	0.014
Bitter flavour	0.760	0.000	0.001
Acidic/ sour flavour	0.701	0.000	0.001
Stickiness	0.891	0.000	0.016
Creamy mouthfeel	0.899	0.000	0.016
Smoothness	0.896	0.000	0.009

Highlighted cells indicate significant effects (p-value < 0.010)

The results shown in **Table 7.46** shows that storage time at -2°C maturation has no significant effect on the development of each of the attributes (p-value > 0.010), however maturation time at +4°C does have a significant effect (p-value < 0.010). Therefore, this indicates that holding the cheese at +4°C had the most significant effect on the development of each of the sensory attributes evaluated in this trial. Total holding time was shown to have a significant effect on all attributes at the 99%

level of confidence; with the exception of *rind crunch, stickiness* and *creamy mouthfeel.*

Simple linear regression was carried out to determine the rate of change in the development of each attribute throughout storage at -2^{o}C and across all storage treatments following maturation at +4^{o}C.The intrinsic reactions within the Camembert cheese system which facilitate the development of these attributes are primarily the result of biochemical reactions. Therefore these results are consistent with catalytic reactions whereby an increase in temperature has a positive influence on the rate at which the substrates are consumed and the products appear. **Table 7.47** to shows that the rate of attribute development was faster; either positively or negatively for all attributes at treatments +4^{o}C compared to storage time at -2^{o}C.

Appearance

Camembert cheese is a surface ripened cheese that has a characteristic coat of white mould which is cultivated prior to packaging. The progression of two appearance attributes were monitored, these were:

1. *Whiteness of the mould*
2. *Dryness of the crust*

WHITENESS OF THE MOULD

Figure 7.39 and **Figure 7.40** show that the *whiteness of the mould* decreases with increasing storage time at -2^{o}C and maturation time at +4^{o}C respectively, when compared to the control sample. The surface mould progressed from "VERY white" (11) towards "NOT white" (1) on the 11-point hedonic scale over time. **Table 7.47** shows that rate discolouration of the surface mould Camembert cheese samples increases at a faster rate in samples that were stored at -2^{o}C for up to SIX weeks followed by maturation at +4^{o}C for eight weeks when compared to the control sample (stored at -2^{o}C for up to 14 weeks: *whiteness of the mould* = -0.354 week^{-1}). Maturation time at +4^{o}C, and total holding time were found to have a significant effect on the development of the *whiteness of the mould* development (p-value < 0.010), however storage at -2^{o}C did not (**Table 7.46**).

Table 7.47: Rate of change in the *whiteness of the mould* attribute of Camembert cheese throughout maturation at +4°C: *whiteness of the mould* = [rate] week^{-1} (p-value)

Treatment	**Rate** (week^{-1})	R^2 (%)
Control	-0.354 (0.000)	96.5
-2°C storage (ZERO weeks)	-0.500 (0.002)	97.4
-2°C storage (TWO weeks)	-0.683 (0.006)	93.9
-2°C storage (FOUR weeks)	-0.518 (0.013)	90.5
-2°C storage (SIX weeks)	-0.583 (0.000)	99.4

Linear regression was assumed for this analysis
Highlighted cells indicate significant effects (p-value < 0.010)

The formation of brown discolouration on the surface of Camembert cheese is a relatively sporadic problem and has been shown to not influence the quality of the cheese; however it can lead to financial losses for manufacturers as a result of the unappealing appearance of the product (Hong *et al.,* 1995; Carreira *et al.,* 1998, 2001a, 20002). Enzymatic browning reactions are typically associated with the formation of melanin-like pigments from tyrosine and which arise from the hydrolysis of casein by yeast and mould proteases and peptidases (Bell and Wheeler, 1986; Goodwin and Sopher, 1993; Nichol and Harden, 1993; Coon *et al.,* 1994; Kotob *et al.,* 1995; Carreira *et al.,* 2001a; 2001b).

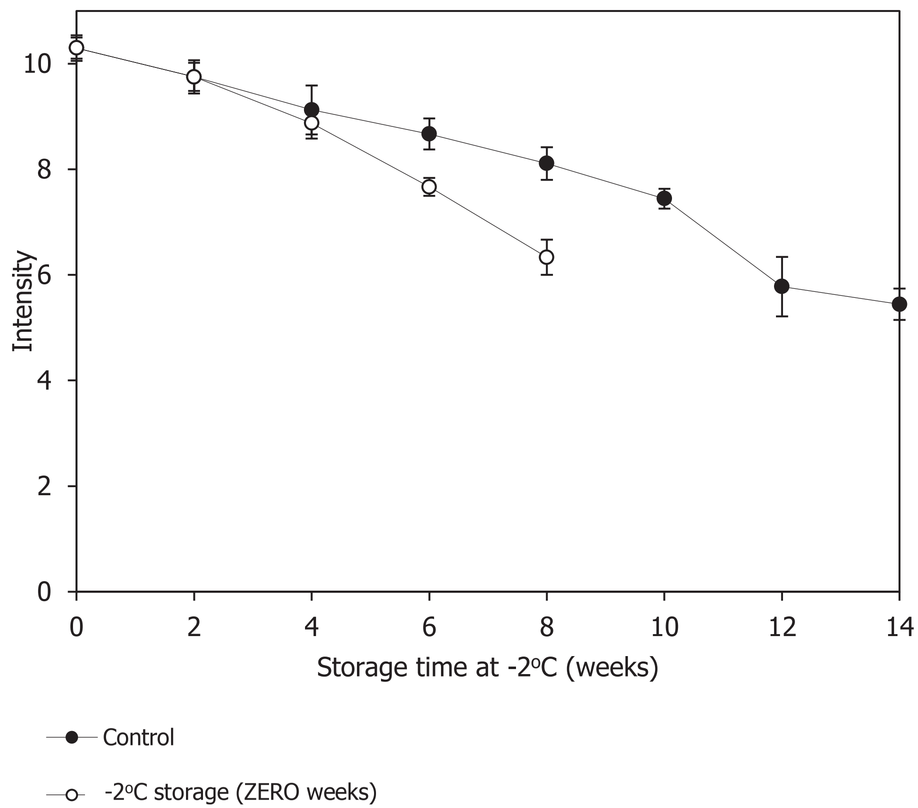
DRYNESS OF THE CRUST

The appearance attribute, *dryness of the crust,* was assessed in comparison to the centre of the cheese sample from a range of "NOT dry" (1) to "VERY dry" (11). **Figure 7.41** and **Figure 7.42** show that the crust of Camembert samples becomes dryer over time. **Table 7.46** shows that maturation time at +4°C had a significant effect on the drying of the crust (p-value =0.000), this was supported by the data shown in **Table 7.48** where the rate of drying throughout maturation at +4°C has greatly increased over maturation time particularly within the -2°C storage (TWO weeks) and -2°C storage (FOUR weeks) samples when compared to the control (storage time at -2°C for 14 weeks: *dryness of the crust* = 0.357 week^{-1}).

Table 7.48: Rate of change in the *dryness of the crust* attribute of Camembert cheese throughout maturation at +4°C: *dryness of the crust* = [rate] week^{-1} (p-value)

Treatment	**Rate** (week^{-1})	R^2 (%)
Control	0.357 (0.000)	94.2
-2°C storage (ZERO weeks)	0.698 (0.004)	95.8
-2°C storage (TWO weeks)	0.905 (0.004)	95.3
-2°C storage (FOUR weeks)	0.796 (0.001)	98.2
-2°C storage (SIX weeks)	0.645 (0.003)	96.6

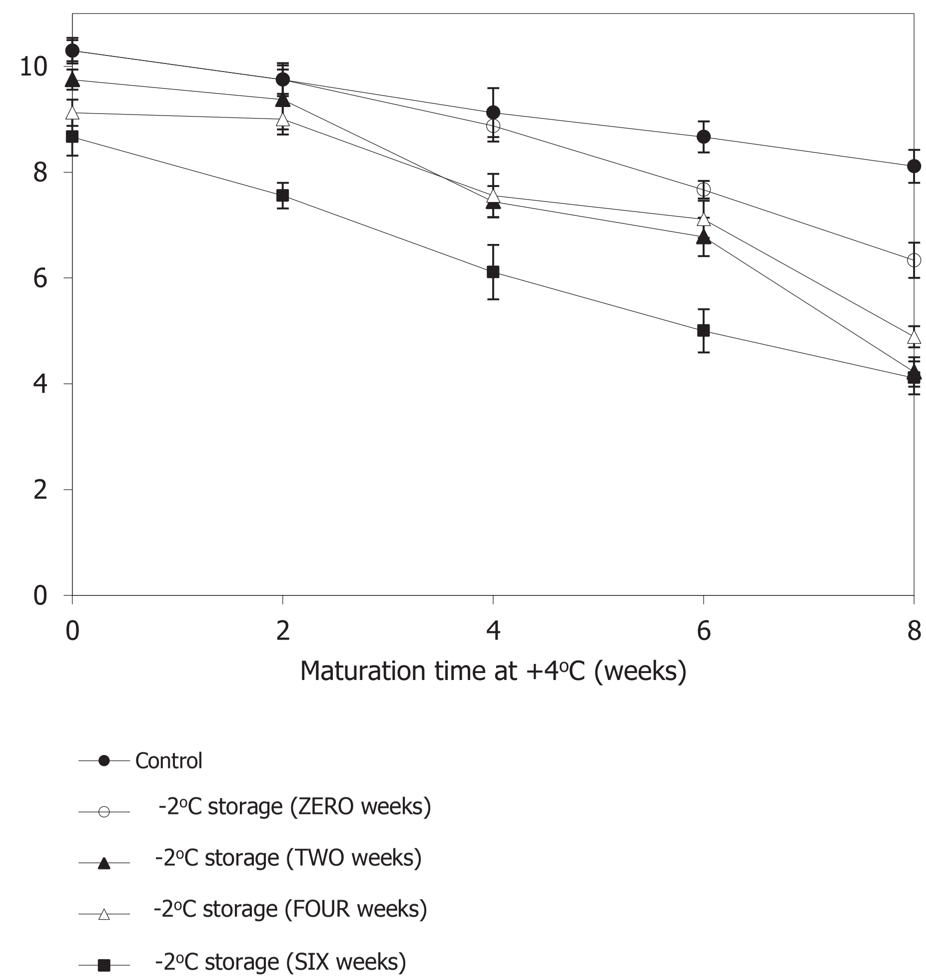
Linear regression was assumed for this analysis
Highlighted cells indicate significant effects (p-value < 0.010)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.39: Trained panel sensory evaluation score for the *whiteness of the mould* throughout storage at -2°C

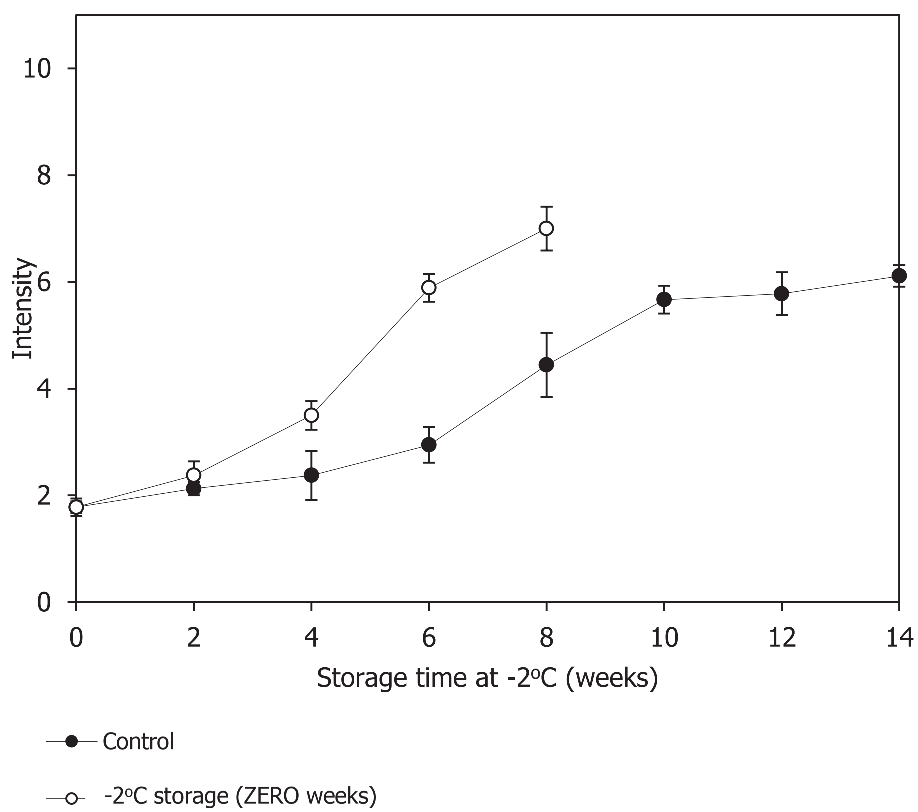
(samples assessed every two weeks, from ZERO weeks storage to SIX weeks storage)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.40: Trained panel sensory evaluation score for the *whiteness of the mould* throughout maturation at +4°C

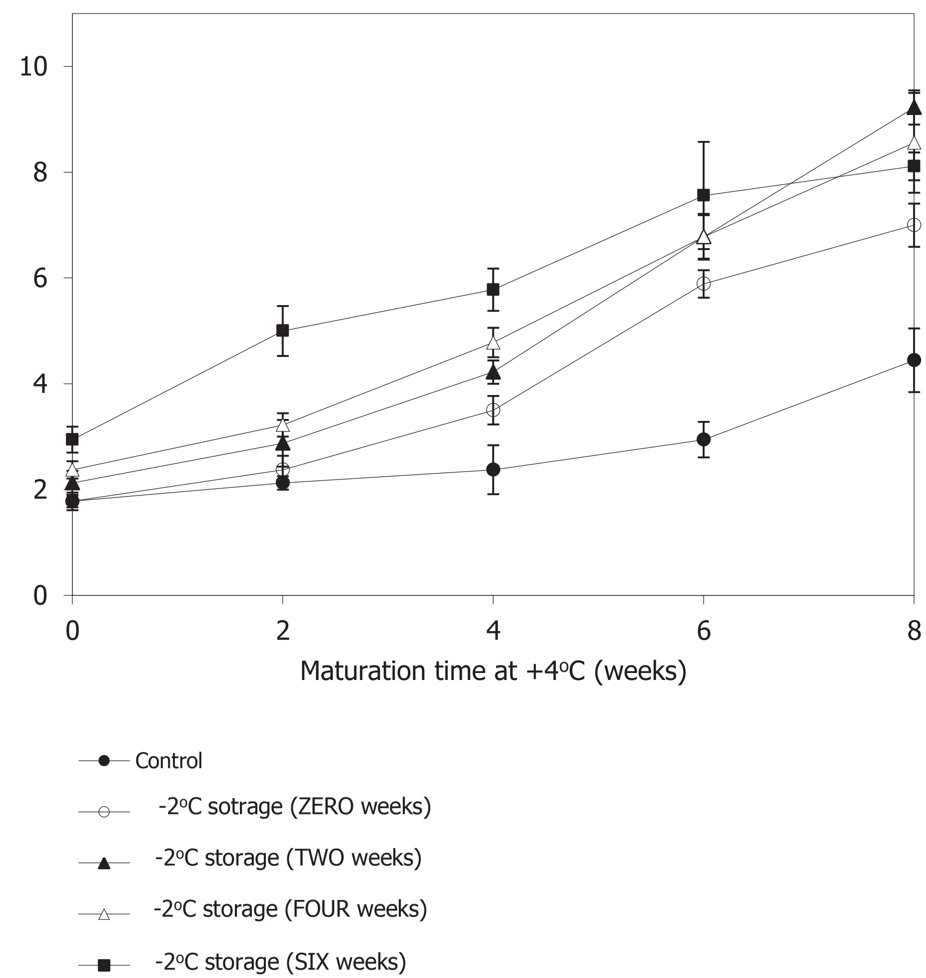
(samples assessed every two weeks, from ZERO weeks maturation to SIX weeks maturation)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.41: Trained panel sensory evaluation score for the *dryness of the crust* throughout storage at -2°C

(samples assessed every two weeks, from ZERO weeks storage to SIX weeks storage)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.42: Trained panel sensory evaluation score for the *dryness of the crust* throughout maturation at +4°C

(samples assessed every two weeks, from ZERO weeks maturation to SIX weeks maturation)

Aroma

Research has shown that the strength of aroma is affected by the temperature of the samples, and the volatility of the aromatic compounds which come into contact with the olfactory system (Carpenter *et al.,* 2000; Meilgaard *et al.,* 2007). The progression of three aroma attributes were monitored, these were:

1. *Mushroom aroma*
2. *Dirty/ stale/ cardboard aroma*
3. *Ammonia aroma*

MUSHROOM AROMA

Figure 7.43 and **Figure 7.44** show that the *mushroom aroma* decreases with increasing storage time at -2^{o}C and maturation time at +4^{o}C respectively. The intensity of this aroma attribute progressed from a score of "VERY mushroom aroma" (11) towards "NO mushroom aroma" (1) on the 11-point hedonic scale over time. **Table 7.49** shows that storage at -2^{o}C resulted in increased rates of *mushroom aroma* development occurring in the Camembert cheese samples throughout maturation at +4^{o}C. Maturation time at +4^{o}C, and total holding time were found to have a significant effect on the development of the *mushroom aroma* development (p-value < 0.010), however storage at -2^{o}C did not (**Table 7.46**).

Table 7.49: Rate of change in the *mushroom aroma* attribute of Camembert cheese throughout maturation at +4^{o}C: *mushroom aroma* = [rate] week^{-1} (p-value)

Treatment	Rate (week^{-1})	R^2 (%)
Control	-0.388 (0.000)	91.5
-2^{o}C storage (ZERO weeks)	-0.690 (0.006)	94.0
-2^{o}C storage (TWO weeks)	-0.694 (0.002)	97.5
-2^{o}C storage (FOUR weeks)	-0.645 (0.001)	98.7
-2^{o}C storage (SIX weeks)	-0.526 (0.015)	89.3

Linear regression was assumed for this analysis
Highlighted cells indicate significant effects (p-value < 0.010)

DIRTY/ STALE CARDBOARD AROMA

The intensity of the *dirty/ stale/ cardboard aroma* attribute was from a range of "NO dirty/ stale/ cardboard aroma" (1) to "VERY dirty/ stale/ cardboard aroma" (11). **Figure 7.45** and **Figure 7.46** show that the *dirty/ stale/ cardboard aroma* in Camembert samples becomes more intense over time. **Table 7.46** shows that maturation time at +4^{o}C had a significant effect (p-value < 0.010), where as storage time at -2^{o}C did not have a significant effect on this aroma attribute (p-value >

0.010). These results are supported by the data shown in **Table 7.50** where the rate of *dirty/ stale/ cardboard aroma* development throughout maturation at +4^{o}C has increased considerably across all samples that had been matured at +4^{o}C when compared to the control which was stored at -2^{o}C for 14 weeks (0.450 week^{-1}).

Table 7.50: Rate of change in the *dirty/ stale/ cardboard aroma* attribute of Camembert cheese throughout maturation at +4^{o}C: *dirty/ stale/ cardboard aroma* = [rate] week^{-1} (p-value)

Treatment	Rate (week^{-1})	R^2 (%)
Control	0.450 (0.000)	88.8
-2^{o}C storage (ZERO weeks)	0.733 (0.006)	94.5
-2^{o}C storage (TWO weeks)	0.675 (0.003)	96.6
-2^{o}C storage (FOUR weeks)	0.664 (0.001)	98.5
-2^{o}C storage (SIX weeks)	0.583 (0.003)	96.4

Linear regression was assumed for this analysis
Highlighted cells indicate significant effects (p-value < 0.010)

The moulds which are selected in the manufacture of Camembert cheese have an impact on the aroma and flavour characteristics which develop. Sensory studies on Camembert cheese samples carried out by Molimard *et al.* (1997) identified mushroom and cardboard as flavour descriptors. The study went on to prove that mushroom descriptor was associated with strains of *Geotrichum candidum* while the cardboard descriptor was associated with strains of *Penicillium camemberti*.

AMMONIA AROMA

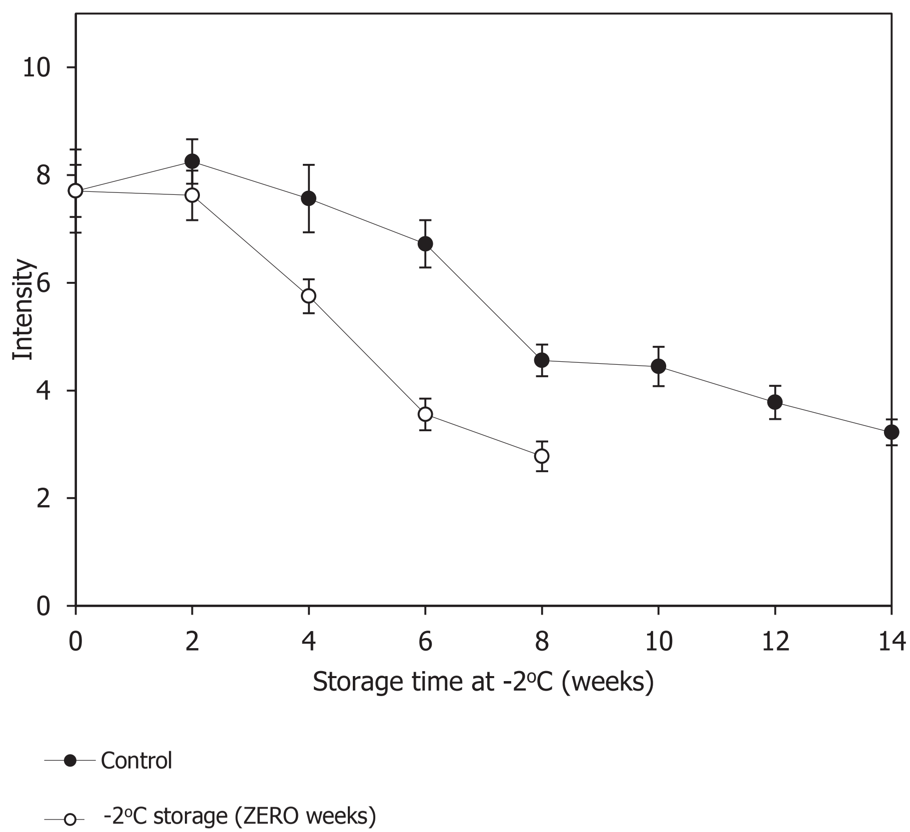
Figure 7.47 and **Figure 7.48** show that the intensity score of the *ammonia aroma* trended from the "NO ammonia aroma" (1) at ZERO weeks towards "VERY ammonia aroma" (11) after SIX weeks, totaling 14 weeks holding time. The rate of *ammonia aroma* development of Camembert cheese is considerably lower when the cheese was stored at -2^{o}C (control sample), compared to the samples which underwent maturation at +4^{o}C (-2^{o}C storage (ZERO, TWO, FOUR and SIX weeks) – see **Table 7.46** shows maturation time at +4^{o}C, and total holding time were found to have a significant effect on the development of the *ammonia aroma* development (p-value = 0.000 and p-value = 0.001 respectively).

Table 7. 51: Rate of change in the *ammonia aroma* attribute of Camembert cheese throughout maturation at +4^{o}C: *ammonia aroma* = [rate] week^{-1} (p-value)

Treatment	**Rate** (week^{-1})	**R^2** (%)
Control	0.457 (0.001)	85.4
-2^{o}C storage (ZERO weeks)	0.946 (0.002)	97.3
-2^{o}C storage (TWO weeks)	0.745 (0.007)	93.4
-2^{o}C storage (FOUR weeks)	0.799 (0.004)	95.8
-2^{o}C storage (SIX weeks)	0.672 (0.011)	88.8

Linear regression was assumed for this analysis
Highlighted cells indicate significant effects (p-value < 0.010)

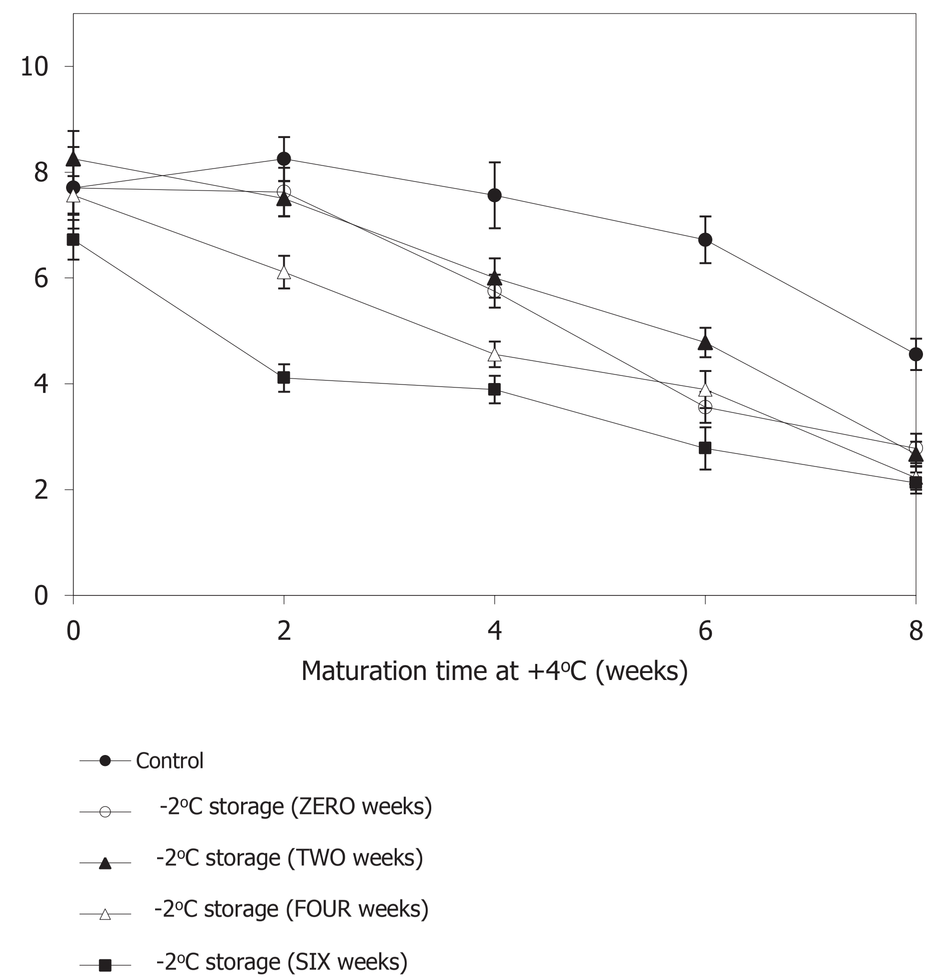
The ammonia note has been correlated directly with the free ammonia concentration, and is a characteristic product of the deamination from amino acids by *Lactobacillus lactis* subspecies *lactis* (Hemme *et al.*, 1982; Crow *et al.,* 1993; Molimard *et al.,* 1994; Adour *et al.,* 2002). The production of ammonia is dependent on the storage temperature and increases throughout ripening, often signalling the end of the shelf life in Camembert cheese (Karahadian and Lindsay, 1987, Crow *et al.,* 1993).



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.43: Trained panel sensory evaluation score for the *mushroom aroma* throughout storage at -2^{o}C

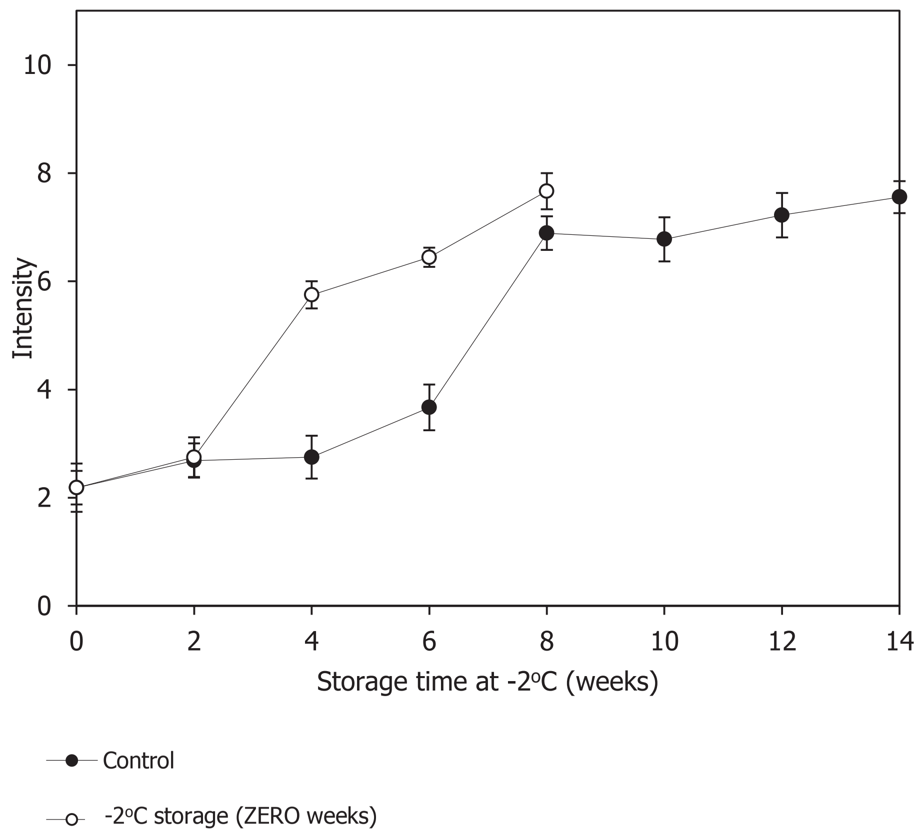
(samples assessed every two weeks, from ZERO weeks storage to SIX weeks storage)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.44: Trained panel sensory evaluation score for the *mushroom aroma* throughout maturation at +4^{o}C

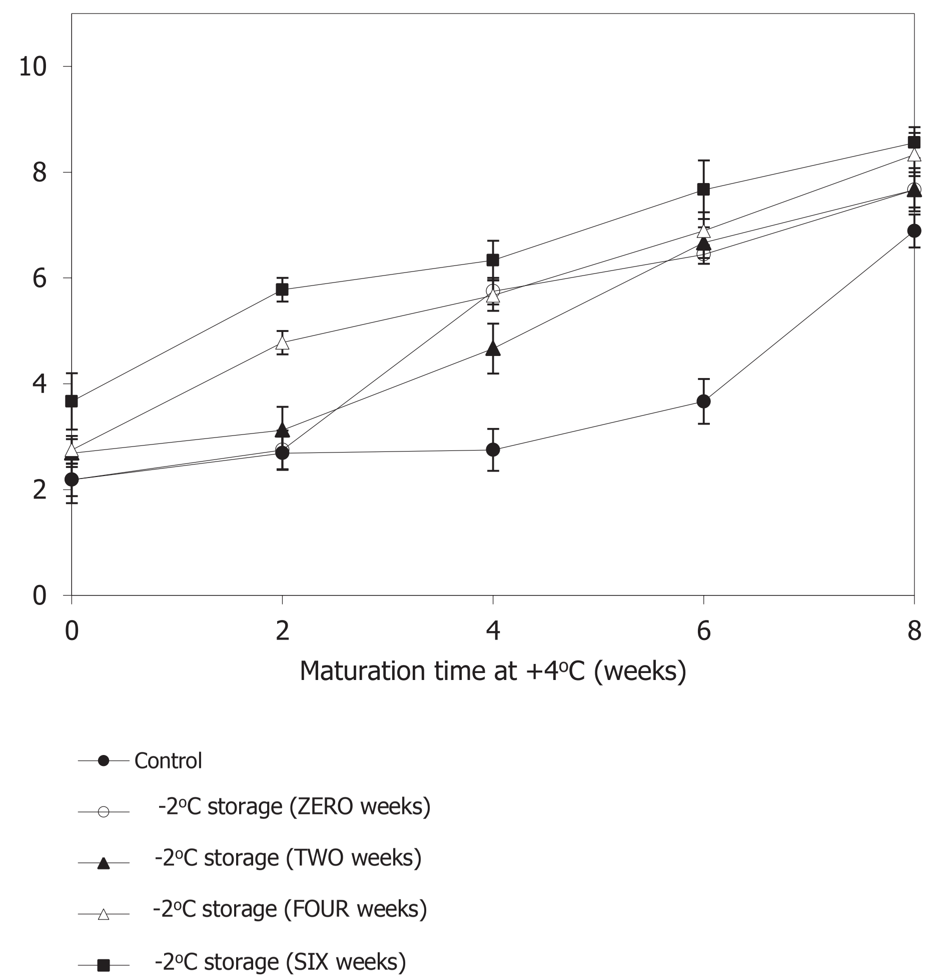
(samples assessed every two weeks, from ZERO weeks maturation to SIX weeks maturation)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.45: Trained panel sensory evaluation score for the *dirty/ stale/ cardboard aroma* throughout storage at -2°C

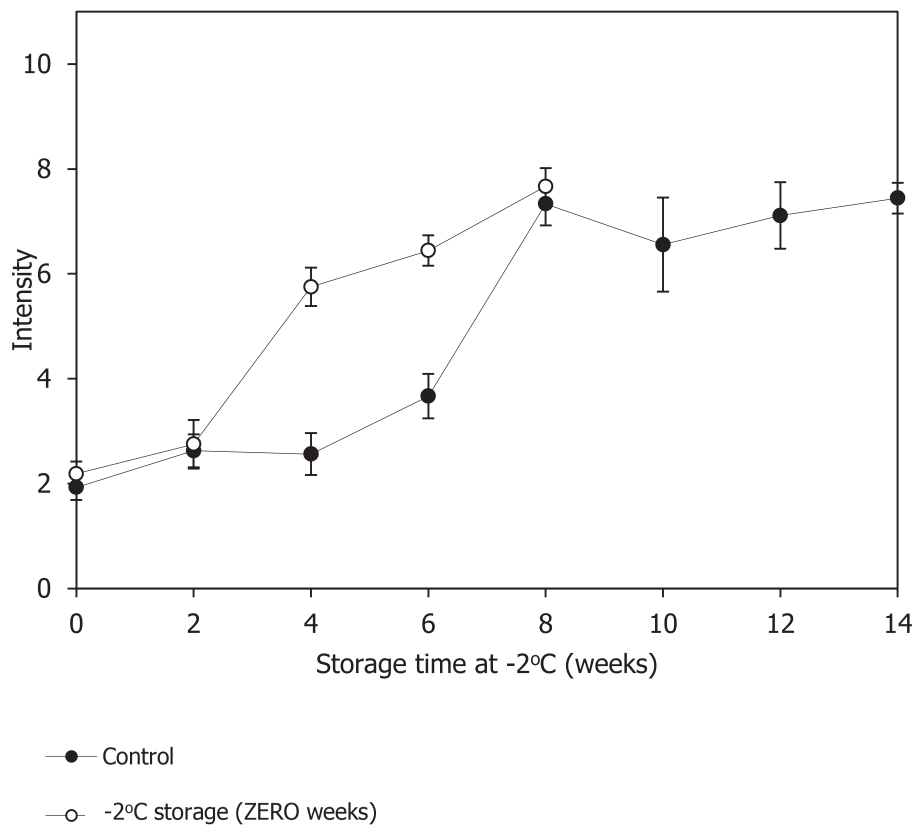
(samples assessed every two weeks, from ZERO weeks storage to SIX weeks storage)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.46: Trained panel sensory evaluation score for the *dirty/ stale/ cardboard aroma* throughout maturation at +4°C

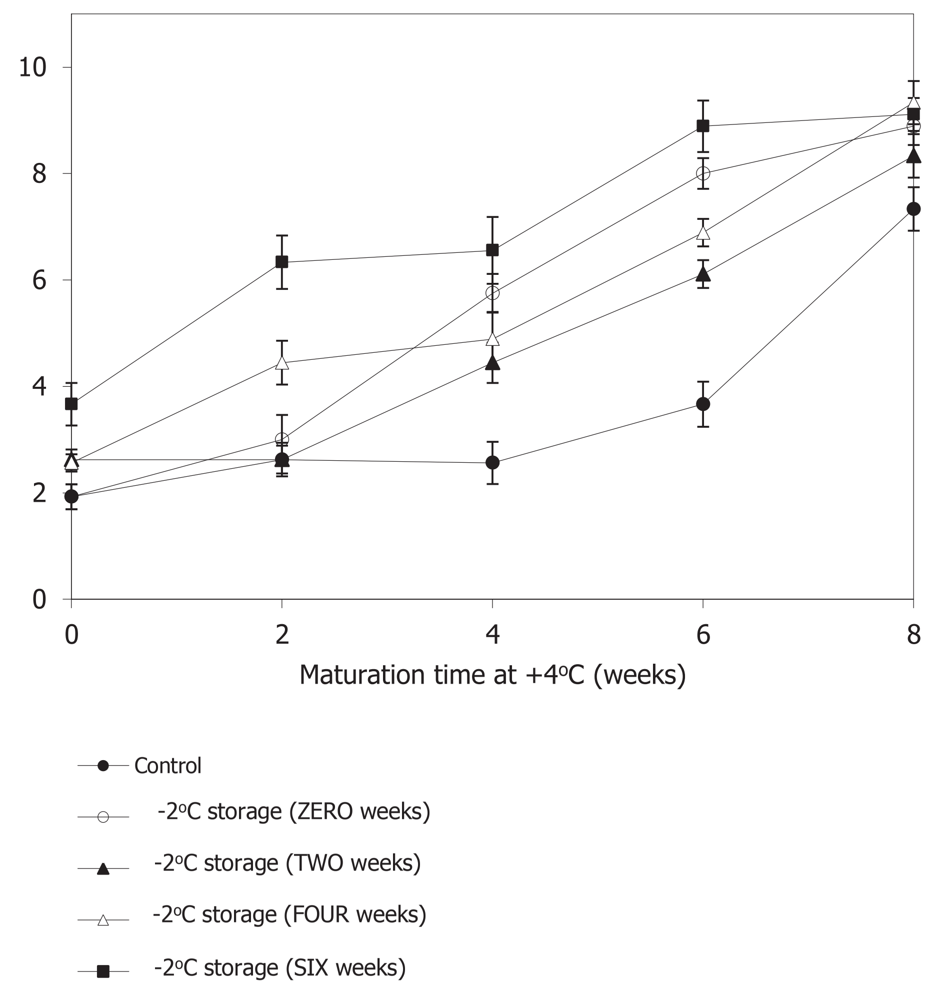
(samples assessed every two weeks, from ZERO weeks maturation to SIX weeks maturation)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.47: Trained panel sensory evaluation score for the *ammonia aroma* throughout storage at -2°C

(samples assessed every two weeks, from ZERO weeks storage to SIX weeks storage)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.48: Trained panel sensory evaluation score for the *ammonia aroma* throughout maturation at +4°C

(samples assessed every two weeks, from ZERO weeks maturation to SIX weeks maturation)

Texture (tactile)

Camembert cheese is known to visibly soften throughout the ripening process whereby the cheese microstructure breaks down from the external surfaces, migrating towards the centre over time (Sousa and McSweeney, 2001). The progression of three texture (tactile) attributes were monitored, these were:

1. *Springiness*
2. *Firmness*
3. *Rindcrunch*

SPRINGINESS

Figure 7.49 and **Figure 7.50** show a negative relationship between the *springiness* of Camembert cheese and total holding time, where the samples progressed from the "VERY springy" (11) towards the "NOT springy" (1) end of the 11-point hedonic scale. **Table 7.52** shows that the rate of *springiness* development decreases with increasing storage temperature; *springiness* progression at -2°C storage = -0.411 week^{-1} compared to *springiness* development -2°C storage (ZERO weeks) = -0.774 week^{-1}. Maturation time at +4°C, and total holding time were found to have a significant effect on the development of the *springiness* development (p-value < 0.010), however storage at -2°C did not (**Table 7.46**).

Table 7.52: Rate of change in the *springiness* attribute of Camembert cheese throughout maturation at +4°C: *springiness* = [rate] week^{-1} (p-value)

Treatment	**Rate** (week^{-1})	**R^2** (%)
Control	-0.411 (0.000)	98.6
-2°C storage (ZERO weeks)	-0.774 (0.004)	95.8
-2°C storage (TWO weeks)	-0.714 (0.002)	97.0
-2°C storage (FOUR weeks)	-0.638 (0.000)	99.4
-2°C storage (SIX weeks)	-0.528 (0.006)	94.2

Linear regression was assumed for this analysis
Highlighted cells indicate significant effects (p-value < 0.010)

FIRMNESS

A negative relationship between the *firmness* of Camembert cheese samples with respect to time (weeks) was noted in **Figure 7.51** and **Figure 7.52**. **Table 7.46** shows that maturation at +4°C for up to eight weeks had a significant effect on the *firmness* of Camembert cheese samples (p-value =0.000), and for every one week's maturation at +4°C (ZERO weeks storage at -2°C) the *firmness* score would shift -

0.588 units. Storage at -2°C did not have a significant effect on the *firmness* intensity score.

Table 7.53: Rate of change in the *firmness* attribute of Camembert cheese throughout maturation at +4°C: *firmness* = [rate] week^{-1} (p-value)

Treatment	**Rate** (week^{-1})	R^2 (%)
Control	-0.352 (0.000)	95.5
-2°C storage (ZERO weeks)	-0.588 (0.002)	97.3
-2°C storage (TWO weeks)	-0.692 (0.004)	95.4
-2°C storage (FOUR weeks)	-0.576 (0.013)	90.4
-2°C storage (SIX weeks)	-0.489 (0.003)	96.4

Linear regression was assumed for this analysis
Highlighted cells indicate significant effects (p-value < 0.010)

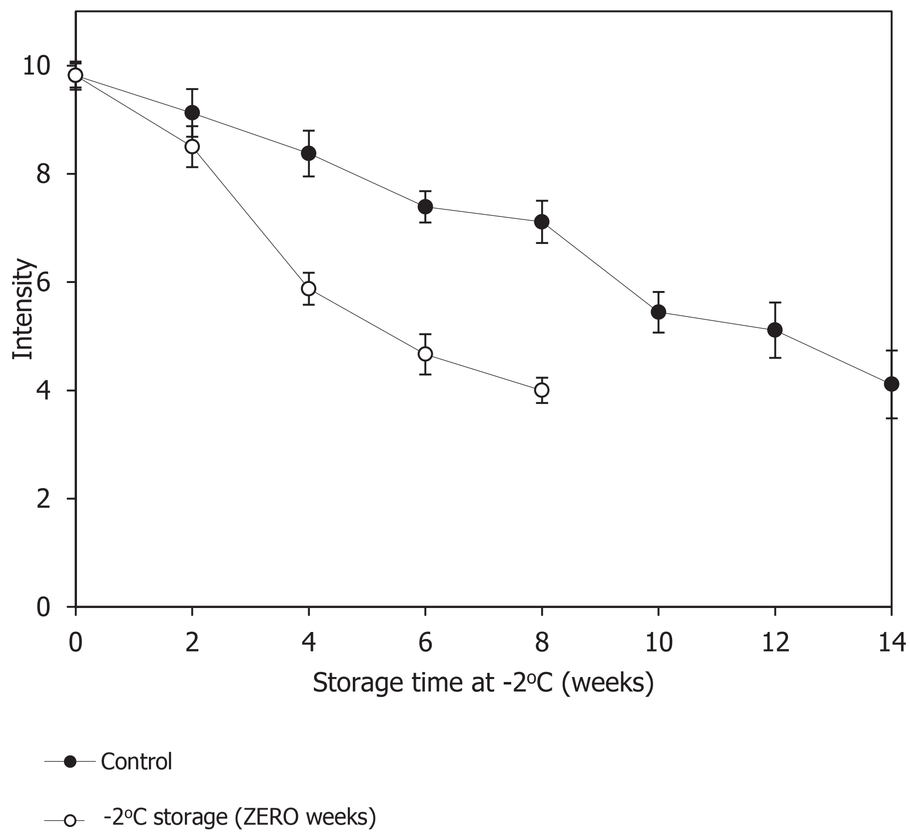
RINDCRUNCH

Rindcrunch is considered an "initial" textural attribute which was assessed by the panellists from the first bite into a cross-section of the cheese sample from a range of "NO rindcrunch" (1) to "INTENSE *rindcrunch*" (11). **Figure 7.53** and **Figure 7.54** show that the rind of Camembert samples thickens and becomes "crunchier" over time. **Table 7.46** shows that maturation time at +4°C had a significant effect on the *rindcrunch* attribute (p-value =0.000), this was supported by the data shown in **Table 7.54** . The rate of "crunch" development is considerably lower when the cheese was stored at -2°C (control sample), compared to the samples which underwent maturation at +4°C (-2°C storage (ZERO, TWO, FOUR and SIX weeks). These results are consistent with those found in the appearance of the *dryness of the crust* attribute.

Table 7.54: Rate of change in the *rind crunch* attribute of Camembert cheese throughout maturation at +4°C: *rind crunch* = [rate] week^{-1} (p-value)

Treatment	**Rate** (week^{-1})	R^2 (%)
Control	0.391(0.000)	97.1
-2°C storage (ZERO weeks)	0.770 (0.015)	89.5
-2°C storage (TWO weeks)	0.700 (0.004)	95.5
-2°C storage (FOUR weeks)	0.663 (0.002)	97.1
-2°C storage (SIX weeks)	0.522 (0.008)	92.9

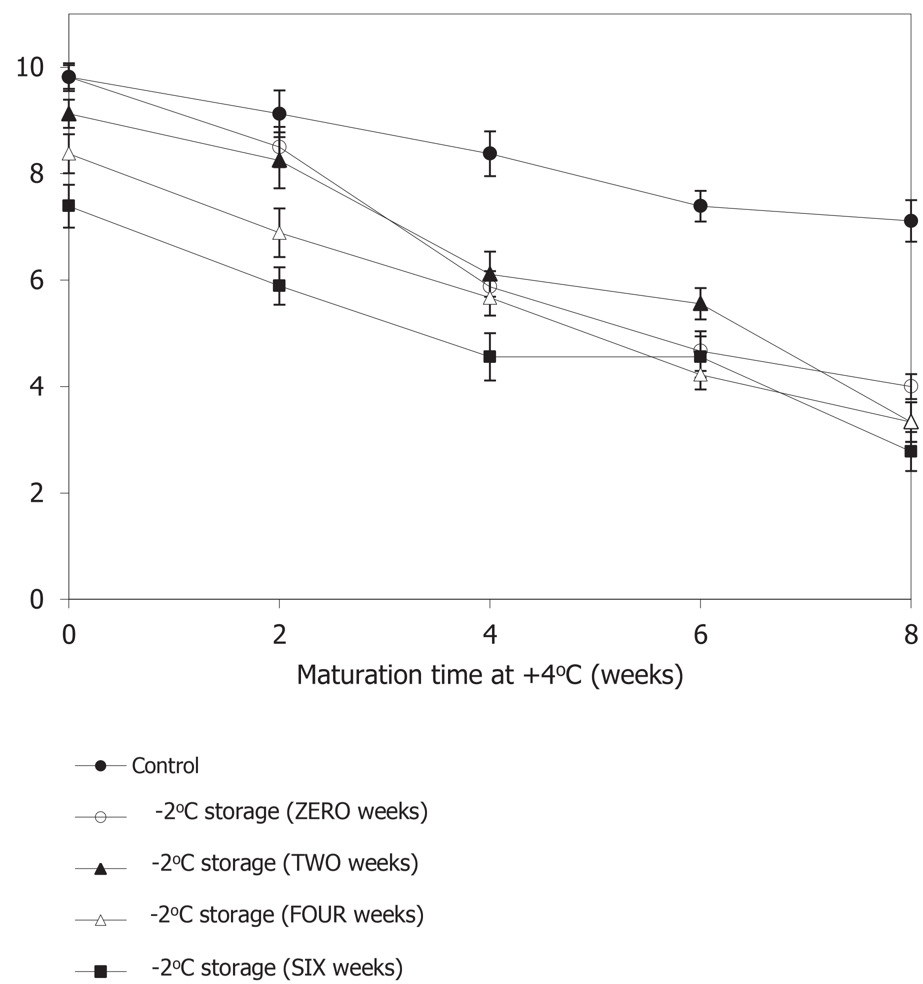
Linear regression was assumed for this analysis
Highlighted cells indicate significant effects (p-value < 0.010)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.49: Trained panel sensory evaluation score for the *springiness* throughout storage at -2°C

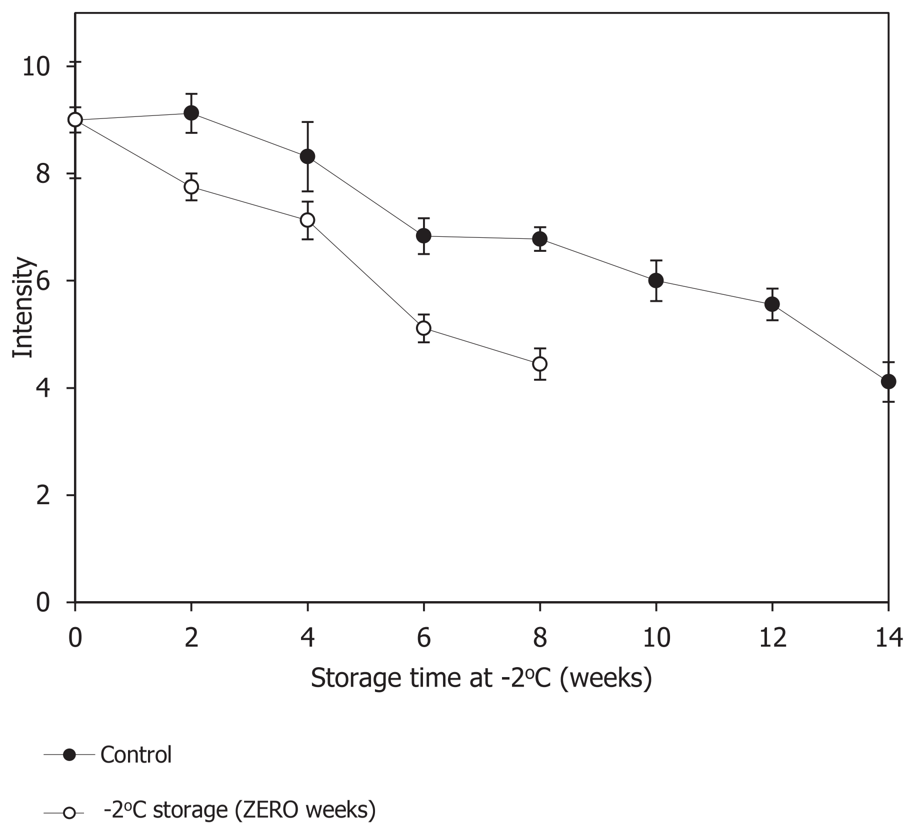
(samples assessed every two weeks, from ZERO weeks storage to SIX weeks storage)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.50: Trained panel sensory evaluation score for the *springiness* throughout maturation at +4°C

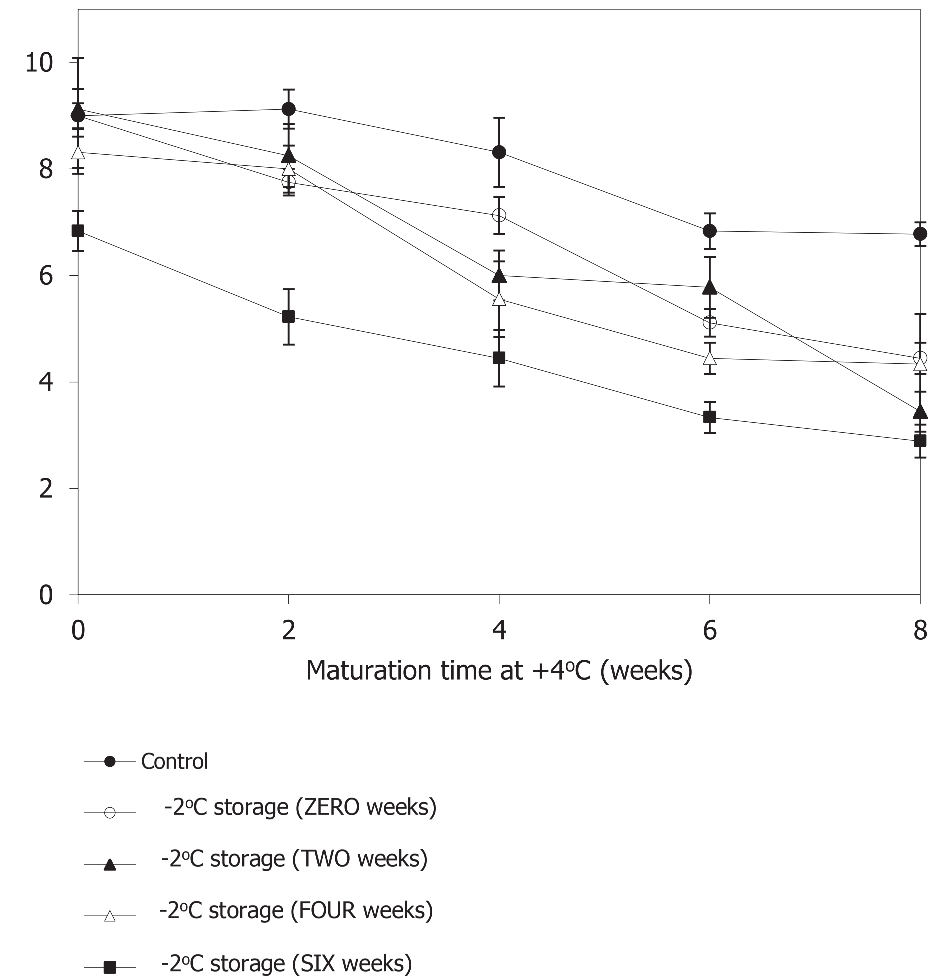
(samples assessed every two weeks, from ZERO weeks maturation to SIX weeks maturation)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.51: Trained panel sensory evaluation score for the *firmness* throughout storage at -2^{o}C

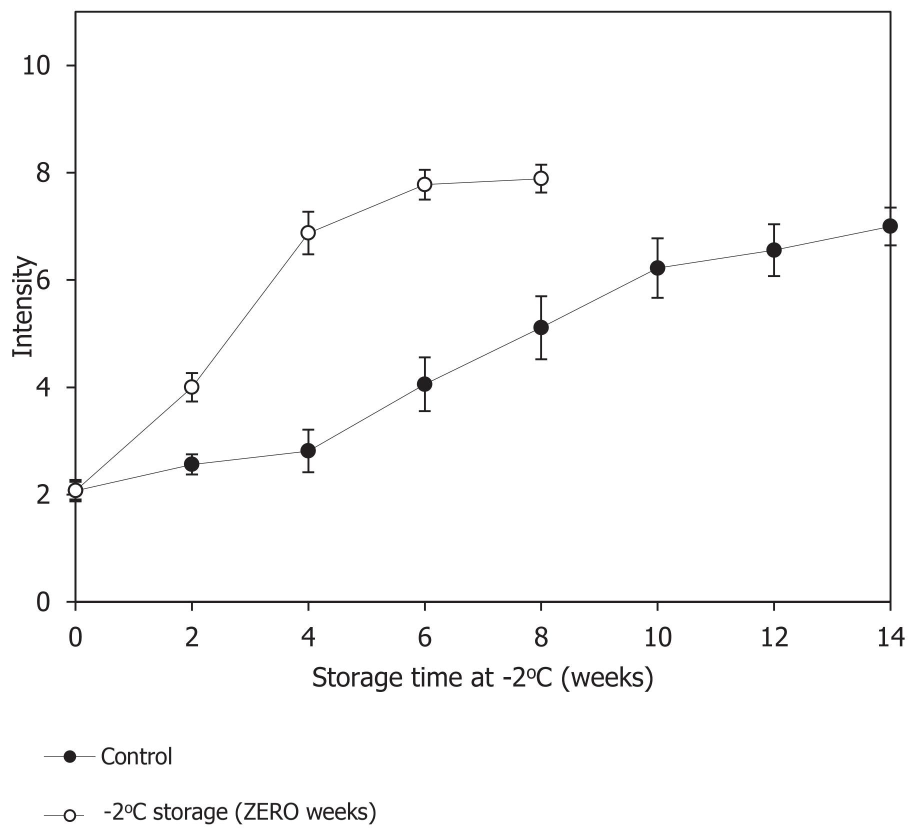
(samples assessed every two weeks, from ZERO weeks storage to SIX weeks storage)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.52: Trained panel sensory evaluation score for the *firmness* throughout maturation at +4^{o}C

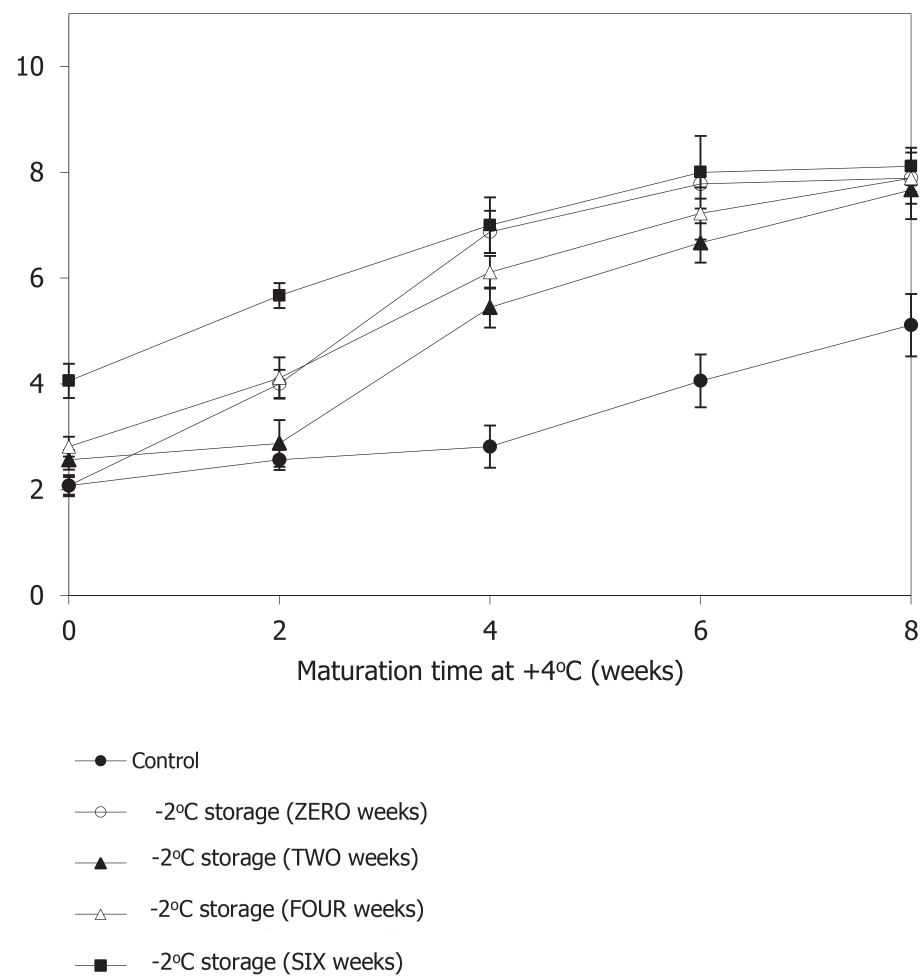
(samples assessed every two weeks, from ZERO weeks maturation to SIX weeks maturation)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.53: Trained panel sensory evaluation score for the *rindcrunch* throughout storage at -2°C

(samples assessed every two weeks, from ZERO weeks storage to SIX weeks storage)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.54: Trained panel sensory evaluation score for the *rindcrunch* throughout maturation at +4°C

(samples assessed every two weeks, from ZERO weeks maturation to SIX weeks maturation)

Flavour

Raw milk quality, interactions between native milk enzymes, enzymes from the rennet, starter bacteria and secondary microflora all impact the characteristic flavour of cheese (Urbach, 1997, Molina *et al.,* 1999, Collins *et al.,* 2003*)* The progression of two flavour attributes were monitored, these were:

1. *Bitter flavour*
2. *Acidic/ sour flavour*

BITTER FLAVOUR

The flavour attribute, *bitter flavour,* was assessed from a range of "WEAK bitter flavour" (1) to "STRONG bitter flavour" (11). **Figure 7.55** and **Figure 7.56** show that the *bitter flavour* increases with increasing storage time at -2^{o}C and maturation time at +4^{o}C respectively. **Table 7.46** shows that maturation time at +4^{o}C had a significant effect on the *bitter flavour* (p-value =0.000), this was supported by the data shown in **Table 7.55** where the rate of flavour development following -2^{o}C storage increased across all samples over maturation time at +4^{o}C when compared to the control (0.395 week^{-1}).

Table 7.55: Rate of change in the *bitter flavour* attribute of Camembert cheese throughout maturation at +4^{o}C: *bitter flavour* = [rate] week^{-1} (p-value)

Treatment	**Rate** (week^{-1})	**R^2** (%)
Control	0.395 (0.000)	97.2
-2^{o}C storage (ZERO weeks)	0.883 (0.013)	90.6
-2^{o}C storage (TWO weeks)	0.839 (0.006)	94.4
-2^{o}C storage (FOUR weeks)	0.740 (0.001)	98.8
-2^{o}C storage (SIX weeks)	0.594 (0.000)	97.5

Linear regression was assumed for this analysis
Highlighted cells indicate significant effects (p-value < 0.010)

Milk which is high in casein (bovine milk) tends to develop higher concentrations of bitter flavours than other milks (ovine or caprine) and the bitter flavour originates more from the nature of the protein, rather than the enzymatic protease that is used (Adda *et al.,* 1982). This characteristic flavour has been attributed to small (500 – 1000Da) hydrophobic peptides originating from both α_{s1} -, and β-casein; and has been associated with the perception of ammonia (Crow *et al.,* 1993; O'Shea *et al.,* 1996; Fox and Wallace, 1997; Engel *et al.,* 2001a, b).

ACIDIC/ SOUR FLAVOUR

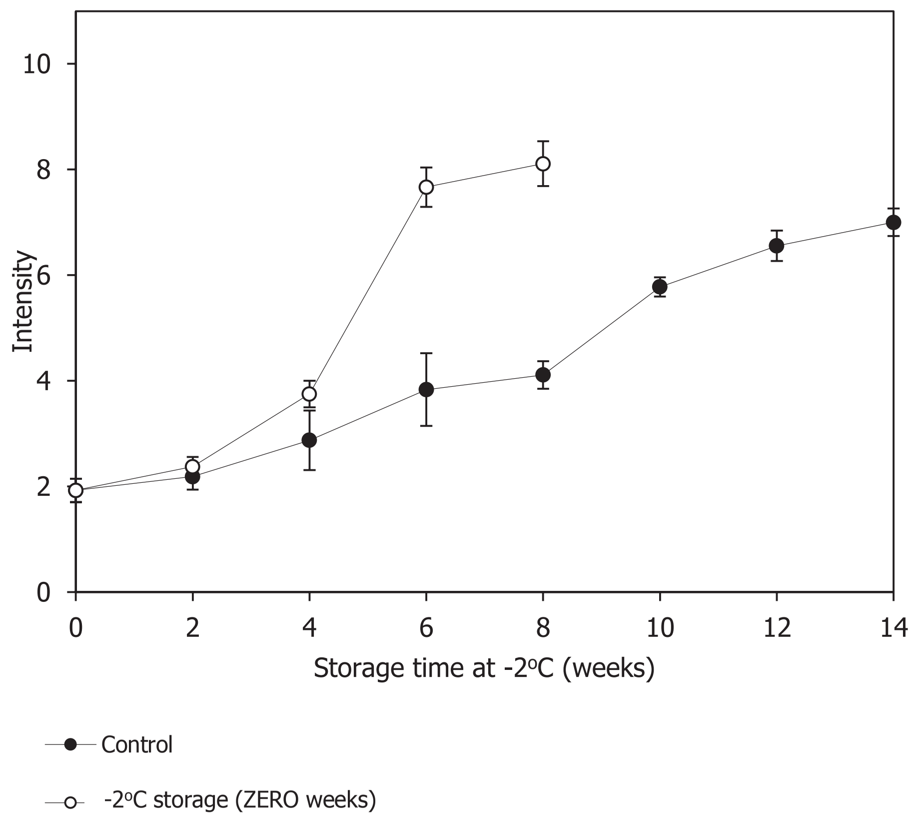
Figure 7.57 and **Figure 7.58** show a negative relationship between the *acidic/ sour flavour* of Camembert cheese and total holding time, where the samples progressed from the "STRONG acidity/ sourness flavour" (11) end of the hedonic scale towards the "WEAK acidity/ sourness flavour" (1) end of the scale. **Table 7.56** shows that the rate at which the *acidic/ sour flavour* Camembert cheese samples increases in between samples that were stored at -2°C for up to 14 weeks (*acidic/ sour flavour* = -0.466 week^{-1}) and samples that were stored at -2°C for up to SIX weeks followed by maturation at +4°C for eight weeks. Maturation time at +4°C, and total holding time were found to have a significant effect on the development of the acid development (p-value = 0.000), however storage at -2°C did not (**Table 7.46**).

Table 7.56: Rate of change in the *acidic/ sour flavour* attribute of Camembert cheese throughout maturation at +4°C: *acidic/ sour flavour* = [rate] week^{-1} (p-value)

Treatment	Rate (week^{-1})	R^2 (%)
Control	-0.466 (0.000)	95.4
-2°C storage (ZERO weeks)	-0.868 (0.010)	91.9
-2°C storage (TWO weeks)	-0.764 (0.004)	95.4
-2°C storage (FOUR weeks)	-0.750 (0.001)	98.3
-2°C storage (SIX weeks)	-0.667 (0.005)	94.7

Linear regression was assumed for this analysis
Highlighted cells indicate significant effects (p-value < 0.010)

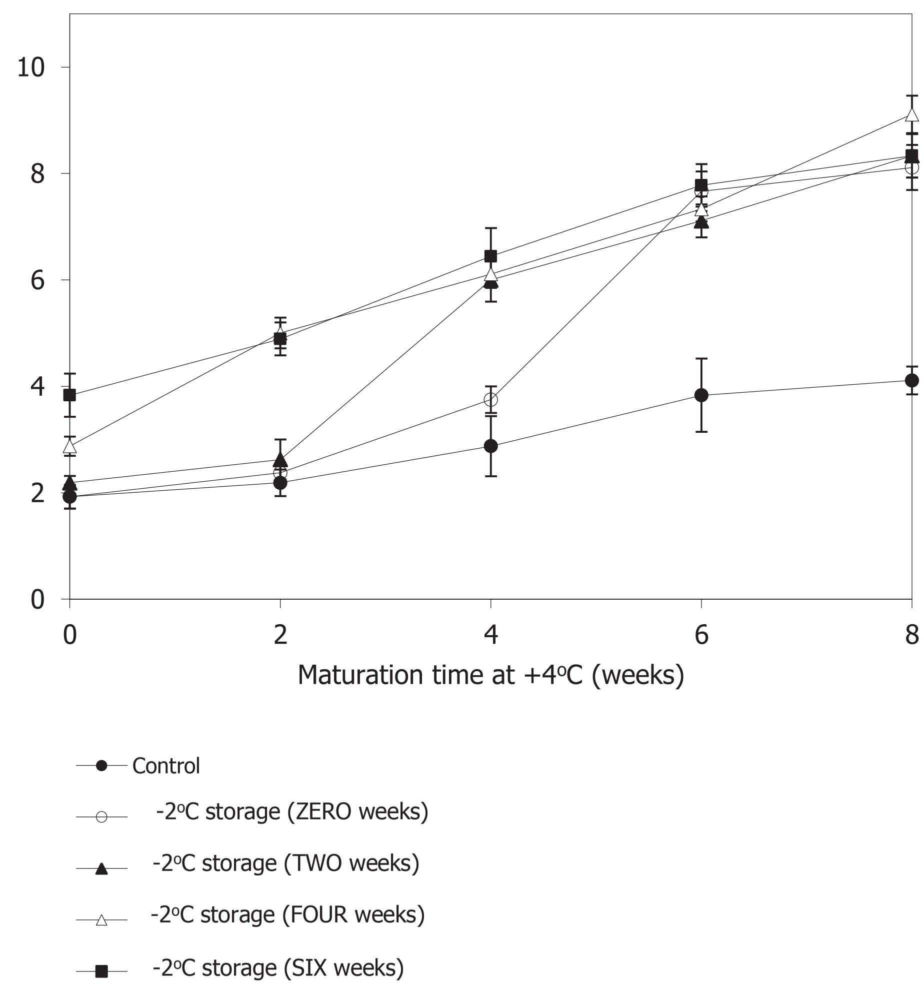
The sour note in Camembert cheese is partially related to the hydrondium (H_3O^+) concentration, which is a bi-product of glycolysis, and decreases for the first 21-days of ripening after which the sourness stabilises (Engel *et al.,* 2001a).



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.55: Trained panel sensory evaluation score for the *bitter flavour* throughout storage at -2°C

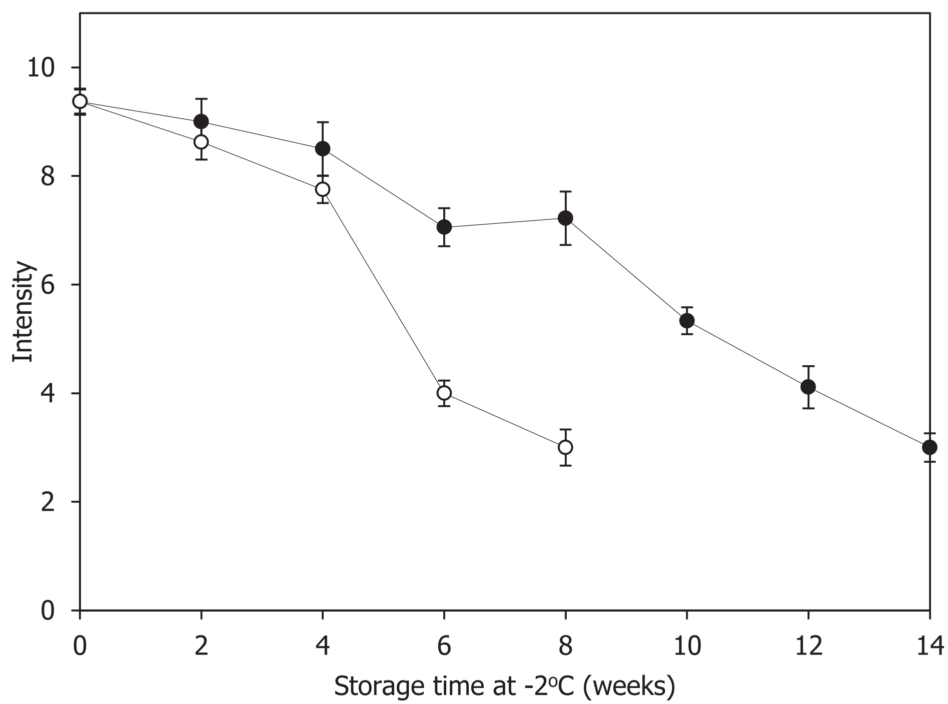
(samples assessed every two weeks, from ZERO weeks storage to SIX weeks storage)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.56: Trained panel sensory evaluation score for the *bitter flavour* throughout maturation at +4°C

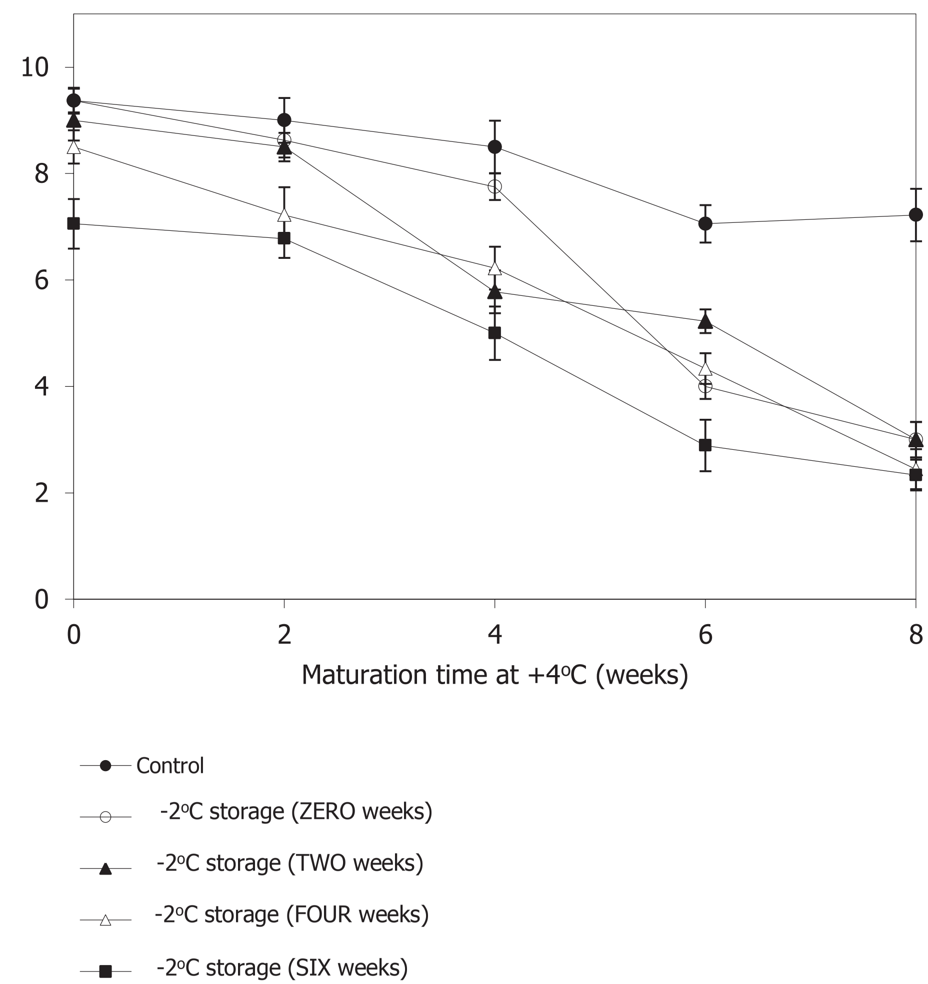
(samples assessed every two weeks, from ZERO weeks maturation to SIX weeks maturation)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.57: Trained panel sensory evaluation score for the *acidic/ sour flavour* throughout storage at -2°C

(samples assessed every two weeks, from ZERO weeks storage to SIX weeks storage)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.58: Trained panel sensory evaluation score for the *acidic/ sour flavour* throughout maturation at +4°C

(samples assessed every two weeks, from ZERO weeks maturation to SIX weeks maturation)

Texture (mouthfeel)

Texture in the mouth is one of the most important quality parameters which determines the characteristics of a cheese and can greatly influence consumer preference (Antoniou *et al.,* 2000). The progression of three texture (mouthfeel) attributes were monitored, these were:

1. *Stickiness of the curd*
2. *Creaminess of the curd*
3. *Smoothness of the curd*

The *stickiness* and *creaminess of the curd* are "masticatory" attributes which were perceived during chewing.

STICKINESS OF THE CURD

Figure 7.59 and **Figure 7.60** show that the *stickiness of the curd* decreases with increasing storage time at -2°C and maturation time at +4°C respectively. Upon mastication, the cheese sample progresses towards from "VERY sticky" (11) towards "NOT sticky" (1) on the 11-point hedonic scale over time. **Table 7.57** indicates that -2°C storage slowed the rate of *stickiness of the curd* development (-0.350 week^{-1}) when compared to the -2°C storage (ZERO) weeks (-0.725 week^{-1}). Maturation time at +4°C was found to have a significant effect on the development of the *stickiness of the curd* development (p-value = 0.000), however storage at -2°C and total holding time did not have a significant effect on the development of this attribute (**Table 7.46**).

Table 7.57: Rate of change in the *stickiness of the curd* attribute of Camembert cheese throughout maturation at +4°C: *stickiness of the curd* = [rate] week^{-1} (p-value)

Treatment	**Rate** (week^{-1})	R^2 (%)
Control	-0.350 (0.000)	94.2
-2°C storage (ZERO weeks)	-0.725 (0.006)	94.1
-2°C storage (TWO weeks)	-0.724 (0.004)	95.7
-2°C storage (FOUR weeks)	-0.554 (0.004)	95.4
-2°C storage (SIX weeks)	-0.472 (0.000)	99.1

Linear regression was assumed for this analysis
Highlighted cells indicate significant effects (p-value < 0.010)

CREAMINESS OF THE CURD

Figure 7.61 and **Figure 7.62** demonstrate that the intensity score of the *creaminess of the curd* trended from the "NOT creamy" (1) at ZERO weeks towards "VERY creamy aroma" (11) after SIX weeks, totaling 14 weeks holding time. The rate development in the *creaminess of the curd* showed a significant increase with an increase in holding temperature: *creaminess of the curd* at -2^{o}C storage = 0.338 week^{-1} compared to *creaminess of the curd* results within samples that were stored at -2^{o}C for up to SIX weeks, followed by maturation at +4^{o}C for eight weeks – see **Table 7.58**. This is supported by results shown in **Table 7.46** whereby maturation time at +4^{o}C had a significant effect on the development of this texture (mouthfeel) attribute (p-value = 0.000).

Table 7.58: Rate of change in the *creaminess of the curd* attribute of Camembert cheese throughout maturation at +4^{o}C: *creaminess of the curd* = [rate] week^{-1} (p-value)

Treatment	**Rate** (week^{-1})	$\mathbf{R^2}$ (%)
Control	0.338 (0.000)	95.5
-2^{o}C storage (ZERO weeks)	0.756 (0.001)	98.6
-2^{o}C storage (TWO weeks)	0.704 (0.005)	94.9
-2^{o}C storage (FOUR weeks)	0.629 (0.001)	97.8
-2^{o}C storage (SIX weeks)	0.633 (0.007)	91.8

Linear regression was assumed for this analysis
Highlighted cells indicate significant effects (p-value < 0.010)

SMOOTHNESS OF THE CURD

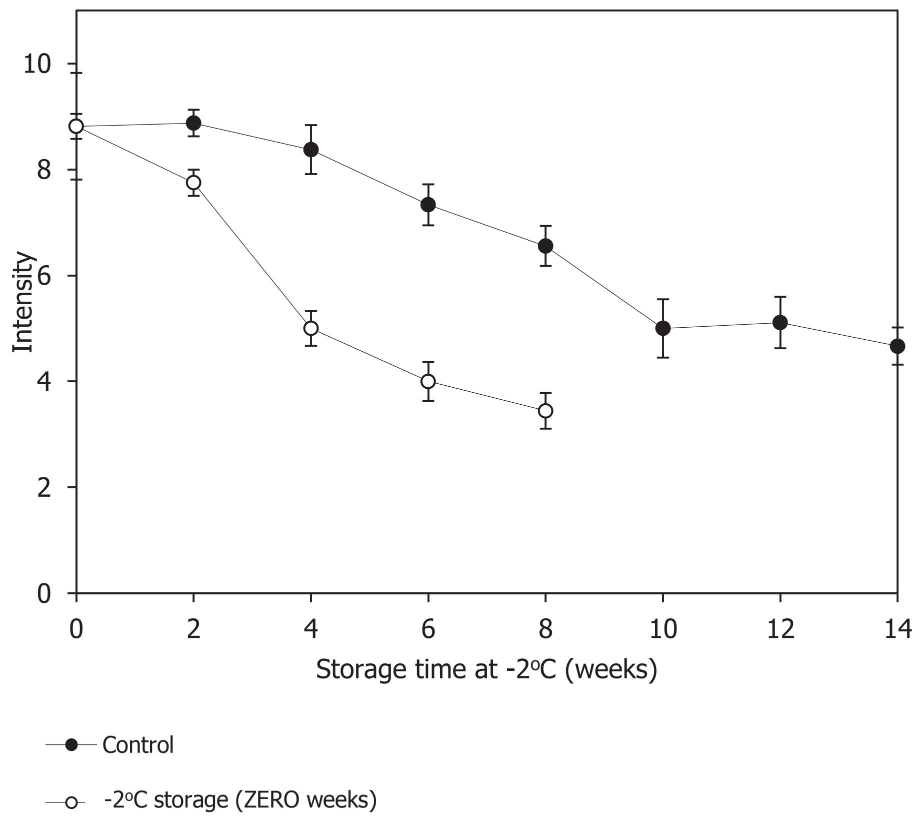
The intensity of the *smoothness of the curd* attribute was assessed from the particulate size following mastication, using a range of "NOT smooth" (1) to "VERY smooth" (11). **Figure 7.63** and **Figure 7.64** show that the *smoothness of the curd* in Camembert samples becomes more increases over time. **Table 7.46** shows that maturation time at +4^{o}C had a significant effect (p-value = 0.000), whereas storage time at -2^{o}C did not have a significant effect on this texture (mouthfeel) attribute (p-value > 0.010). These results are supported by the data shown in

where the rate of *smoothness of the curd* development throughout maturation at +4^{o}C (-2^{o}C storage (ZERO weeks)) has over time (0.806 week^{-1}) when compared to the control which was stored at -2^{o}C for 14 weeks (0.352 week^{-1}).

Table 7.59: Rate of change in the *smoothness of the curd* attribute of Camembert cheese throughout maturation at +4^{o}C: *smoothness of the curd* = [rate] week^{-1} (p-value)

Treatment	**Rate** (week^{-1})	**R^2** (%)
Control	0.352 (0.000)	94.9
-2^{o}C storage (ZERO weeks)	0.806 (0.000)	99.8
-2^{o}C storage (TWO weeks)	0.774 (0.010)	91.9
-2^{o}C storage (FOUR weeks)	0.620 (0.001)	97.4
-2^{o}C storage (SIX weeks)	0.667 (0.009)	92.7

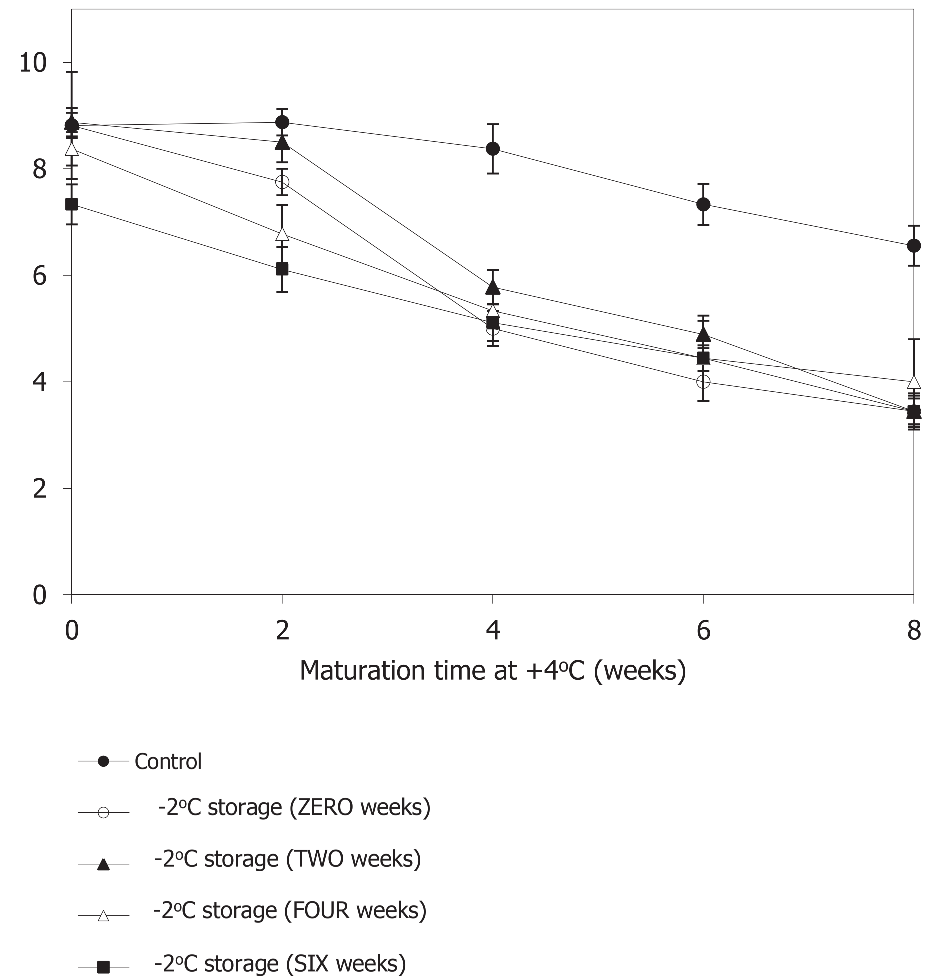
Linear regression was assumed for this analysis
Highlighted cells indicate significant effects (p-value < 0.010)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.59: Trained panel sensory evaluation score for the *stickiness of the curd* throughout storage at -2°C

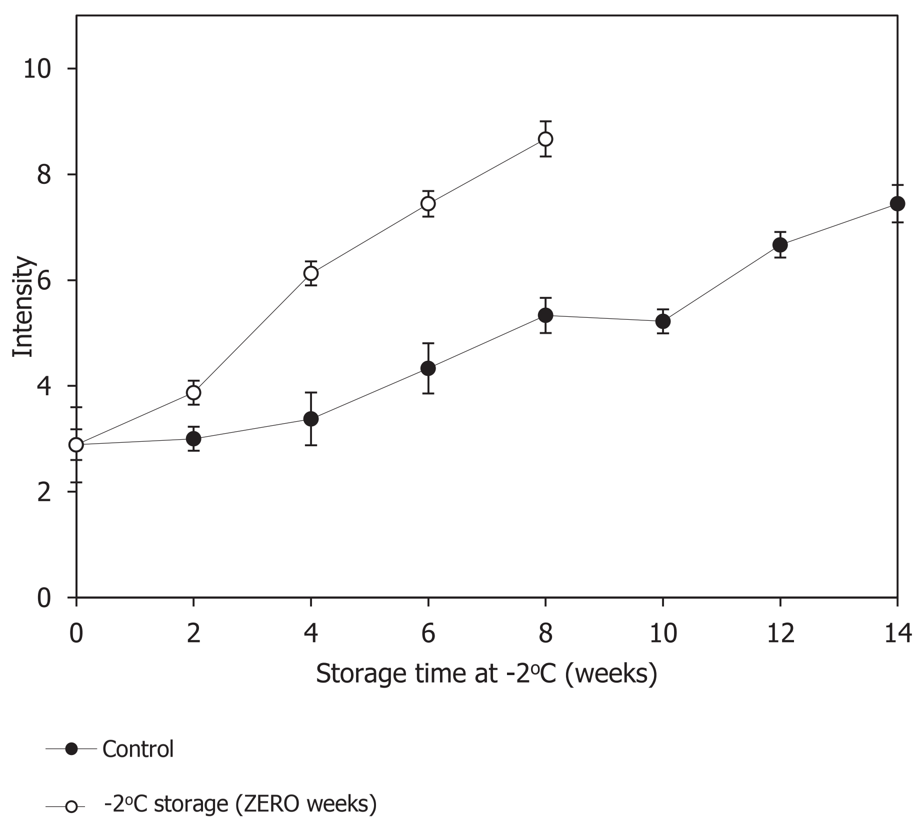
(samples assessed every two weeks, from ZERO weeks storage to SIX weeks storage)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.60: Trained panel sensory evaluation score for the *stickiness of the curd* throughout maturation at +4°C

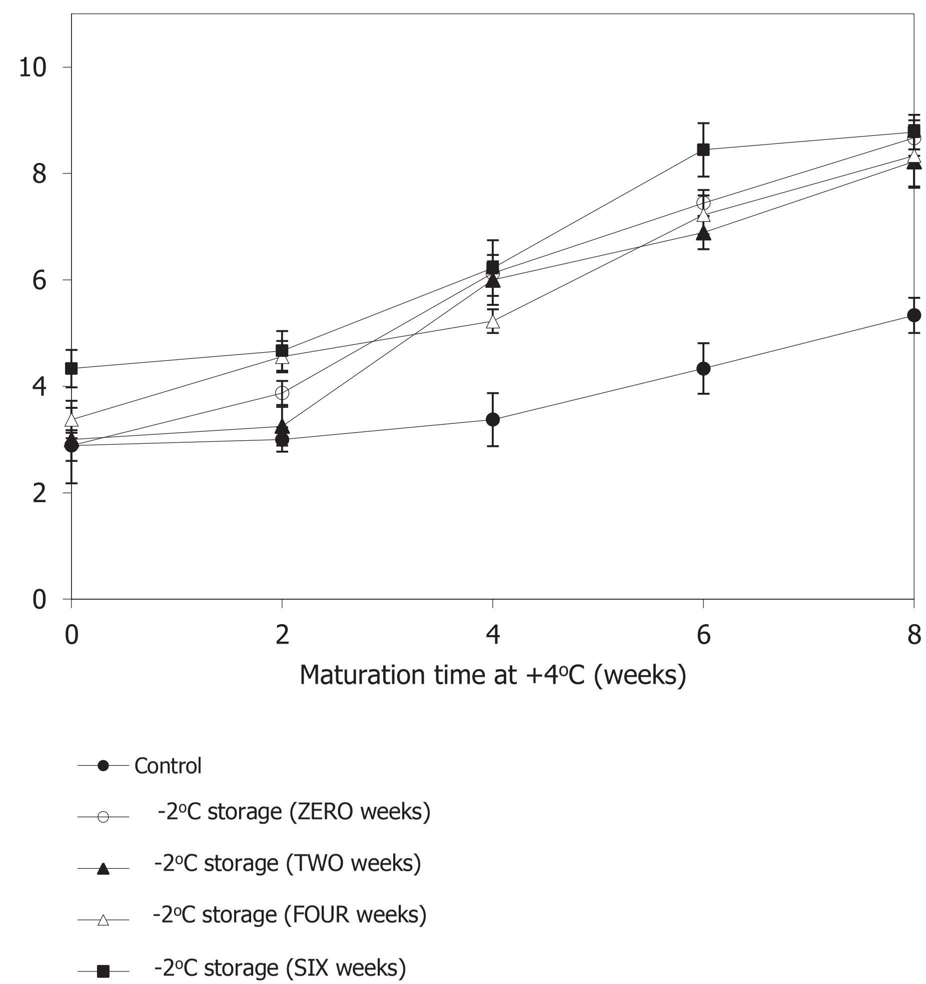
(samples assessed every two weeks, from ZERO weeks maturation to SIX weeks maturation)



Results are representative of an mean panel scores ± standard error (n=9)

Figure 7.61: Trained panel sensory evaluation score for the *creaminess of the curd* throughout storage at -2°C

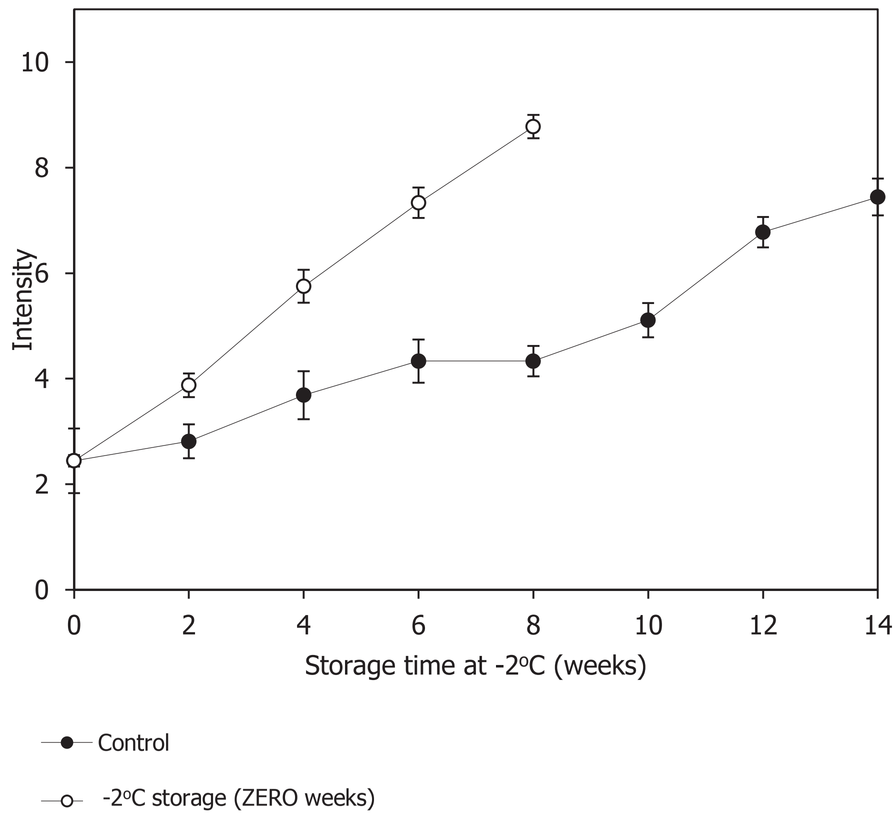
(samples assessed every two weeks, from ZERO weeks storage to SIX weeks storage)



Results are representative of an mean panel scores ± standard error (n=9)

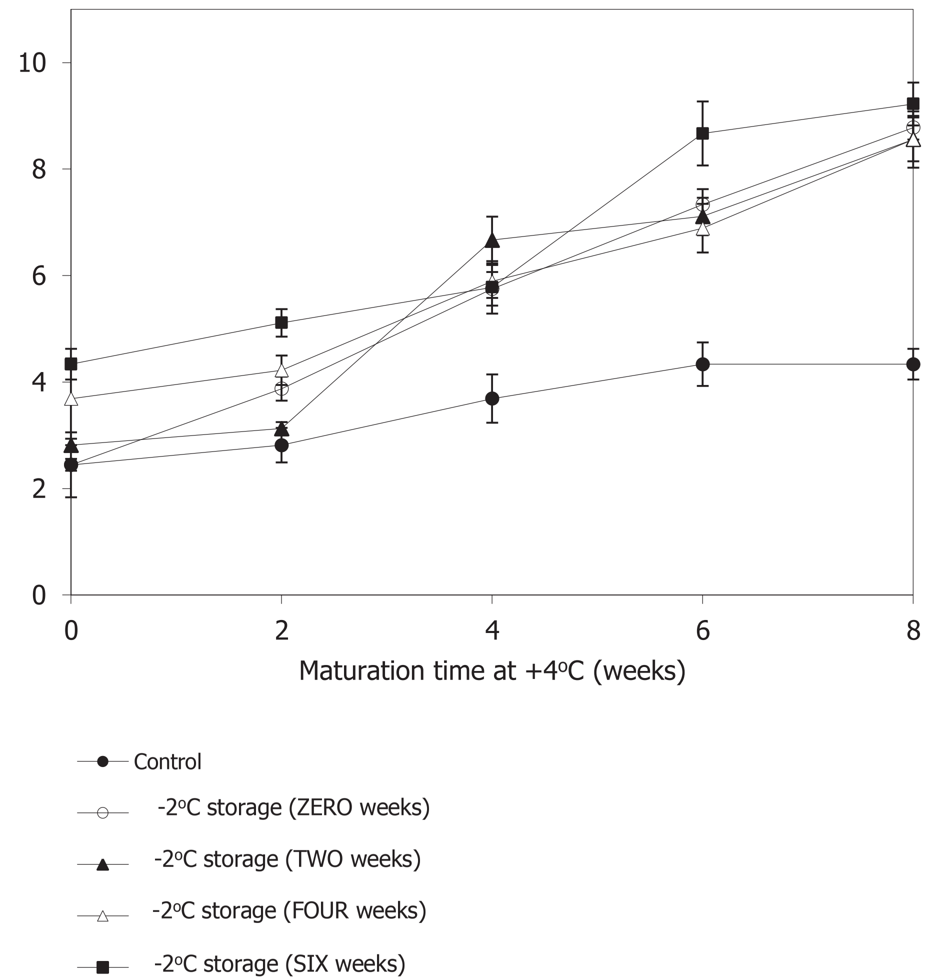
Figure 7.62: Trained panel sensory evaluation score for the *creaminess of the curd* throughout maturation at +4°C

(samples assessed every two weeks, from ZERO weeks maturation to SIX weeks maturation)



Results are representative of an mean panel scores ± standard error (n=9)
Figure 7.63: Trained panel sensory evaluation score for the *smoothness of the curd* throughout storage at -2°C

(samples assessed every two weeks, from ZERO weeks storage to SIX weeks storage)



Results are representative of an mean panel scores ± standard error (n=9)
Figure 7.64: Trained panel sensory evaluation score for the *smoothness of the curd* throughout maturation at +4°C

(samples assessed every two weeks, from ZERO weeks maturation to SIX weeks maturation)

7.5 Correlation between QDA results and stage TWO compositional and textural analysis research

Correlation analysis between the QDA results and the stage TWO compositional (moisture content and pH), protein indices (pH 4.4 SN/ TN and TCA SN/ TN) and textural results (uniaxial compression and puncture force) was carried out to determine which maturation properties were responsible for sensory characteristics - **Table 7.60**.

Strong statistically significant correlations (R >± 0.75; p-value > 0.010) were observed between the QDA attributes and the stage TWO maturation properties. This is consistent with what would be expected in soft, mould ripened cheeses where all of the maturation processes are interdependent on one another other as seen in **Chapter 6.41:** *Correlations between compositional and textural analysis research*.

The pH of Camembert cheese progresses from approximately 5.0 and rises to approximately 7.5 to 8.0 towards the end of the products shelf life (Adda *et al.,* 1982; Karahadian and Lindsay, 1987; Fox and Wallace, 1997; Lucey *et al.,* 2003). The results shown in **Table 7.60** demonstrate a negative relationship between pH and the *acidic/ sour flavour* (correlation = -0.979 with the pH of the inside portion and -0.875 the pH of the outside portion).

Table 6.27 showed a strong negative correlation between Moisture content (%) and puncture force (N) (-0.935), which was supported by Bonaïti *et al.* (2004) who reported that the cheese crust thickens over time. These two maturation properties were also shown to have a strong correlation with the QDA appearance attribute: *dryness of the crust* (correlation = -0.875 with moisture content (%) and -0.875 with puncture force (N)); and the QDA tactile texture attribute: *rind crunch* which was perceived on the first bit into the cheese sample (correlation = -0.915 with moisture content (%) and 0.898 with puncture force (N)).

Table 7.60: Correlations between QDA results and Stage TWO compositional and textural analysis research

	Inside pH	Outside pH	Moisture content	pH 4.4 SN/ TN	TCA SN/ TN	Uniaxial compression	Puncture test
Whiteness of the mould	-0.962	-0.847	0.881	-0.925	-0.937	0.936	-0.851
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Dryness of crust	0.949	0.850	-0.875	0.961	0.922	-0.-17	0.875
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mushroom aroma	-0.953	-0.884	0.905	-0.923	-0.901	0.926	-0.866
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Dirty/ stale/ cardboard	0.945	0.899	-0.942	0.917	0.905	-0.935	0.905
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ammonia	0.931	0.875	-0.902	0.971	0.889	-0.922	0.878
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Springy	-0.954	-0.939	0.925	-0.944	-0.911	0.916	-0.916
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Firmness	-0.948	-0.892	0.889	-0.928	-0.897	0.927	-0.861
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rind crunch	0.904	0.927	-0.915	0.934	0.878	-0.881	0.898
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bitter	0.948	0.891	-0.886	0.953	0.899	-0.879	0.881
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Acidic/ sour	-0.979	-0.875	0.899	-0.954	-0.934	0.917	-0.889
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
stickiness	0.914	-0.918	0.908	-0.932	-0.871	0.863	-0.896
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
creamy	0.931	0.879	-0.887	0.973	0.919	-0.902	0.910
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Smoothness	0.930	0.889	-0.875	0.964	0.920	-0.904	0.920
	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Pearsons Correlation
P-value
Highlighted cells indicate significant correlations (p-value > 0.010)

Table 7.60 shows strong correlations between the protein indices results (pH 4.4 SN/ TN and TCA SN/TN) and the *ammonia aroma*, *bitter flavour*, *creamy texture* (mouthfeel) and *smoothness texture* (mouthfeel):

The correlation between the *ammonia aroma* and the pH 4.4 SN/ TN and TCA SN/ TN was found to be 0.971 and 0.889 respectively. The ammonia aroma that is associated with Camembert cheese is typically identified in the final stage of ripening where the proteolytic enzymes deaminate the amino acids formed from peptides (Sousa et al., 2001; Coker et al., 2004; McSweeney, 2004).

The pH 4.4 SN/ TN and TCA SN/ TN was shown to have correlation of 0.953 and 0.899 respectively with the *bitter flavour* attribute in this QDA research. The *Penicillium* species has been shown to release proteolytic enzymes which are responsible for the appearance of high molecular weight peptides which have been correlated to the *bitter flavour* in Camembert cheese (Molimard *et al.,* 1994 and Molimard *et al., 1997;* Boutrou *et al.,* 2001; Engel *et al*., 2001a).

Initially the texture of Camembert cheese is very brittle and crumbly, however studies have shown that proteolysis breaks down the peptides within the cheese matrix contributing to a softening of the texture within cheese matrix (Antoniou *et al.,* 2000; McSweeney, 2004). With this breakdown in the cheese structure the curd becomes less grainy in its texture therefore influencing the *creamy* and *smoothness* attributes. **Table 7.60** shows that a positive correlation existed between the protein indices (pH 4.4 SN/ TN and TCA SN/ TN) and the texture (mouthfeel) attributes (*creamy* and *smoothness*). These were:

- *Creamy mouthfeel* correlated with pH 4.4 SN/ TN = 0.973
- *Creamy mouthfeel* correlated with TCA SN/ TN = 0.919
- *Smoothness* of the curd following mastication with pH 4.4 SN/ TN = 0.964
- *Smoothness* of the curd following mastication with TCA SN/ TN = 0.920

Similarly with the structural integrity of Camembert cheese decreasing throughout maturation, a strong positive correlation between the uniaxial compression (N.mm) and the texture (tactile) attributes *springy* and *firmness*. Therefore based on the decrease in the uniaxial compression results over time, the *springy* and *firmness* attributes could be predicted to an accuracy of 91.6% and (92.7%)

7.6 Outcomes of Quantitative Descriptive Analysis (QDA) trials

From these trials it was found that:

1. Storage time at -2^{o}C did not have a significant or detrimental effect on the sensory properties of Camembert cheese that were investigated in this report;
2. From the Simple linear regression analysis, it was found that -2^{o}C storage slowed the rate at which the intensity of each sensory attribute developed when compared to the -2^{o}C storage (ZERO, TWO, FOUR and SIX weeks);
3. Strong and statistically significant correlations were able to be drawn between the QDA results and the Stage TWO compositional and textural analysis research.

8.0 Final discussion

The freezing profile of a single unit of Camembert cheese was found to start at -3.0^{o}C and continue to -3.5^{o}C. In order to minimise the formation of small ice crystals which may affect the structural integrity of the cheese samples, and reduce the development of potential microbiological and enzymatic changes; a rapid form of chilling was established in order to reduce cheese samples to below zero, but above the actual freezing point, as recommended by Lück (1977). To achieve this, individual units were placed on a ventilated bread tray, ≈0.35m from the fan unit (set at -18.7±1^{o}C.)

Slow defrosting of the Camembert cheese following chilling has also been found to be advantageous in preserving the quality of the cheese (Lück, 1977; Verdini and Rubiolo, 2002a). The slowest method of tempering was achieved by re-packing the cheese samples into the cardboard cases, ready for the distribution chain, and tempering them in a chiller unit set at +4±1^{o}C.

Various storage time temperature combinations, followed by eight weeks maturation at +4^{o}C, were investigated to understand their impact on the maturation and organoleptic properties; and consumer acceptability of Camembert cheese samples. These were:

Stage ONE trials	Stage TWO trials
• Control (+4^{o}C for 8 weeks)	• Control (-2^{o}C for 14 weeks)
• +1^{o}C storage (ONE, TWO, THREE and FOUR weeks)	• -2^{o}C storage (ZERO weeks)
• -2^{o}C storage (ONE, TWO, THREE and FOUR weeks)	• -2^{o}C storage (TWO weeks)
• -10^{o}C storage (ONE, TWO, THREE and FOUR weeks)	• -2^{o}C storage (FOUR weeks)
	• -2^{o}C storage (SIX weeks)

The severity of the Stage ONE: -10^{o}C (FOUR weeks) storage regime on both the cheese texture (samples became more crumbly and did not soften throughout maturation) and the cheese microflora (concentrations of the surface moulds decreased throughout storage, therefore indicating that the samples were stored below the minimum growth temperature of the organism) was shown to have a significant effect on the maturation properties of Camembert cheese samples. Research shows that by reducing the concentration of the surface microflora following storage influences the extent of the important biochemical reactions which contribute to the characteristic appearance, flavour, aroma of the product (Leclercq-Perlat *et al.*, 1999).

Controlling the temperature of Camembert cheese samples at -2^{o}C for up to SIX weeks (Stage TWO) was found to reduce the rate of important biochemical reactions, without having a significant impact on the maturation properties which would influence the compositional, textural or organoleptic properties of the cheese throughout maturation at +4^{o}C for eight weeks (p-value < 0.010). It was following -2^{o}C storage (throughout the maturation period at +4^{o}C) that the rate of the sequential biochemical reactions within soft mould ripened cheeses are increased allowing the characteristic texture aroma and flavour to develop. Strong statistically significant correlations (R >± 0.75; p-value > 0.010) were observed between:

1) All of the stage TWO maturation properties (moisture content and pH, protein indices: pH 4.4 SN/ TN and TCA SN/ TN; and textural results: uniaxial compression and puncture force) that were studied as part of this research
2) The QDA attributes and the stage TWO maturation properties

These findings support the literature whereby it has been extensively acknowledged that the ripening process of soft, mould ripened cheeses are induced by a sequential process of biochemical reactions (Smit *et al.*, 2002).

Consumer sensory analysis showed that storing cheese samples at -2^{o}C for up to SIX weeks followed by maturation at +4^{o}C for eight weeks results in an "acceptable" cheese. A significant difference was observed between several of the samples that were tested in terms of the *appearance* (shown by the p-value being less than 0.010). Consumer comments of these samples relates particularly to a "grey", "yellow" or "brown" "unappealing" discolouration of the surface mould. As freezing is a desiccation process, studies have shown that packaging can effectively be used to optimise the extent of moisture loss, discolouration of the surface mould and rind thickening over time by adding a hydrosorbent layer and micro-perforations to the internal surface of Camembert cheese packaging (Mathlouthi *et al.,* 1994).

9.0 Conclusions and recommendations

From the results found within this master's thesis, it can be concluded that:

1. The freezing profile of Camembert cheese was shown to start at -3.0°C and continue to -3.5°C which was achieved after 36 to 69 minutes (respectively).
2. The most rapid method of chillin was achieved by placing individual units of Camembert ≈ 0.30m from the fan unit in a freezer unit at -18.7±1°C. This was achieved within 23 – 26 minutes;
3. The slowest method of tempering was achieved by tempering the cheese in the cases in a chiller unit set at +4±1°C
4. The severity of the Stage ONE storage of treatment at: -10°C (FOUR weeks) was shown to have a significant effect on the maturation properties for: *Uniaxial compression; work,* and *Enumeration of yeasts and moulds;*
4. Storing Camembert cheese at -2°C for up to SIX weeks, followed by maturation at +4°C for eight weeks successfully controlled the rate of maturation for all maturation properties that were investigated (*moisture content, pH of the centre* and *outside portions, pH 4.4 SN/ TN, TCA SN / TN, uniaxial compression* and *puncture testing*);
5. Consumers showed "overall liking" and "preference" for samples which had been treated with -2°C storage (TWO weeks) and -2°C storage (SIX weeks). The -2°C storage (FOUR weeks) sample consistently gave anomalous results in comparison to the other samples, which may have been due to batch variation from this reverse storage trial;
6. Storage time at -2°C did not have a significant or detrimental effect on the sensory properties of Camembert cheese that were investigated in this report;
7. From the Simple linear regression analysis, it was found that -2°C storage slowed the rate at which the intensity of each sensory attribute developed when compared to the -2°C storage (ZERO, TWO, FOUR and SIX weeks);
8. Strong and statistically significant correlations were able to be drawn between the QDA results and the Stage TWO compositional and textural analysis research.

Recommendations for Puhoi Valley Cheese Ltd. include:

1. Schedule increased frequency/ volume production runs for Bouton d'or Camembert 125g (product code: 569044) for high demand periods at least 14 weeks prior to start

feeding the market (using storage regime: -2^{o}C storage (SIX weeks) followed by eight weeks maturation at +4^{o}C)

2. Develop a mechanism to chill individual units of Camembert cheese to -2^{o}C
3. Package individual units into cases ready for distribution chain and thawing at +4^{o}±C

10.0 References

A

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11.0 Appendix

Product Specification Sheet

Product Portfolio

Product Code	569220
Product Description	Puhoi Camembert 210g
Manufacturing Division/s	Puhoi Valley Cheese, Ahuroa Road, Puhoi, New Zealand
Processing Line	Traditional & White Mould Wrap
Date	8 March 2007
Version Number	02 – change in ingredient, allergen and address

Main Characteristic

Puhoi Camembert is a fresh, soft cheese which has a mild, even flavour and appeals to the majority of cheese eaters. It has a smooth creamy mouthfeel with a subtle mushroom flavour.

Packaging Description

White foil wrap with green and white adhesive label, centred on front of cheese. Grey and white label on back of cheese printed with nutritional information, ingredients listing, barcode, batch number and 'best before' date (day, month, year).

QC Laboratory Requirements:		Required (Y/N)	
Test Requirements	RM Clearance	Y	Reference NZDF QC Laboratory Manuals
	Batch Tank Clearance	Y	
	Finished Product Clearance	Y	
	Retention Samples	Y	
Sampling Plan	NZDF Standard Sampling plan as detailed in Laboratory manual	Y	
Release System	Positive	Y	

FINISHED PRODUCT SPECIFICATIONS		
Microbiological		
Standard	**Range**	**Units**
Coliform	<500	cfu/g
Yeast & Moulds	N/A (White Mould Product)	cfu/g
Chemical		
Standard	**Range**	**Units**
Fat	28 – 32	%
Total Solids	49 – 55	%
Physical		
Standard	**Target**	
pH post brining	4.90 – 5.30	
Sensory	White Mould: no tanning or off flavours, clean mushroom flavour, soft creamy texture.	

Packaging Configuration

Dimensions of Pack	H		W		D		Units per case	6
Cheese	110	X	110	X	30	mm	Cases per layer	15
Case	70	X	300	X	200	mm	Layers per pallet:	10
Barcode product:			9 415652 692205				Cases per pallet:	150
Barcode outer	FS		1 94 15652 692202				Approx gross pallet weight:	226.1 kg
Barcode outer	PW		1 94 15652 692646					

LABEL INFORMATION

Applicable Foods Standards	Australia New Zealand Food Standards Code Code of Practice on Nutrient Claims in Food Labels and in Advertisements
Food Identification Requirements	**Label Text**
Name of the Food	Camembert
Lot Identification	Batch number stated on pack - 0DDD# (0=Trad, DDD=Julian, #=Run Number)
Name and Address of Supplier	Puhoi Valley Cheese, Ahuroa Road, Puhoi, New Zealand
Ingredients	**Contains milk as indicated in bold type.** Pasteurised Cow's **Milk**, **Cream**, Salt, Cultures, Enzyme (Non Animal Rennet).
Net Weight:	210g
Date Marking of Packaged Food	Use By: DD MMM YY (label change required – change to 'Best Before')
Storage Conditions	Keep Refrigerated Between 1-4^{0}C
Use Instructions	Best eaten at room temperature
Nutrition Information Serving Size: 30 g Servings per Pack: 7	(see Nutrition Information panel below)

NUTRITION INFORMATION	average quantity per serving		average quantity per 100 g	
ENERGY	422	kJ	1404	kJ
PROTEIN	5.0	g	16.0	g
FAT – total	9.0	g	30.0	g
– saturated	6.0	g	19	g
CARBOHYDRATES – total	<1	g	1.0	g
– sugars	<1	g	<1	g
SODIUM	224	mg	746	mg
CALCIUM (18% of RDI)	146	mg	486	mg

RDI Recommended Dietary Intake

Note for artwork: if a value is '0', state on label as "<1"

Font Size	No legal requirement, other than legibility
Use of the word Natural	Both the Code of Practice and the NZ Commerce Commission have issues with using the word natural. A natural food should not contain additives such as flavour, colour, preservatives etc. It should not have any integral part removed or changed. It is up to the marketer of the product to ensure they are not misleading consumers.
Other (No legal requirements or	• FOR RECIPE & FURTHER INFORMATION PLEASE CALL OUR FREEPHONE (NZ ONLY) 0800 423 133

restrictions)	• www.puhoicheese.co.nz

All labels must also comply with:

- Weights and Measures Act 1987
- Fair Trading Act 1986

DECLARATIONS

1.	Product Name	Camembert Cheese
2.	Product Shelflife	7 Weeks from Date of Pack
3.	Packaging Material, integrity of packaging	White perforated wrap
4.	Declaration of allergens and certain specific ingredients	
	•Cereals containing gluten	
	•Crustaceans and their products	
	•Eggs and egg products	
	•Fish and fish products	
	•Milk and milk products	Contains Cow's Milk
	•Nuts and sesame seeds and their products	May Contain Traces of Nuts
	•Peanuts and their products	
	•Soybeans and their products	
	•Added sulphites	
	•Bee pollen, Royal Jelly, Propolis	
	•Polyols	
	•Aspartame	
	•Quinine	
	•Guarana	
	•Phytosterols	
	•Added Caffeine	
	•Soy or rice milk products	
	•Unpasteurised egg	
	•Unpasteurised milk and liquid milk products	
5.	Country of Origin	New Zealand
6.	GMO status; please indicate one of the following	
	• The material/product is not made with gene technology, nor does it contain components produced with gene technology; the material/product does not contain novel DNA and/or protein and does not have altered characteristics.	✓
	• The material/product is made with gene technology, or contains components produced with gene technology; it contains novel DNA and/or protein, or has altered characteristics.	
	• The material/product is made with gene technology, but is highly refined; the refining process has removed novel DNA and/or protein. It has no altered characteristics.	
	• The material/product is a processing aid or food additive containing novel DNA and/or protein, but the novel DNA and/or protein will not be present in the food it will be added to.	
	• The material/product is a flavour, made with gene technology, but will be added to a food in a concentration less than 1g /kg.	
7.	Quality Systems; indicate type of systems in place, certification etc	ISO 9001:2000
8.	Food borne pathogens; indicate if any are associated with the product/material; give detail in microbiological standards	
9.	Chemical hazards; indicate if any hazards are associated with the product/material	
10.	Cheese Production Type: eg: Feta, Camembert	Traditional Camembert

PRODUCTION PROCEDURE
Puhoi Valley Cheese Co. Ltd (PVC) produces this product, according to the recipe. This recipe cannot be changed unless sign off is agreed from all who sign this spec.
A sample is taken at production and QC tested at PVC.
Eight retention samples are kept and are graded over the shelf life of the product. The product must average a 3 at these grading to be acceptable.

PACKING PROCEDURE
The product is hand wrapped and packed on-site, where it is produced after ripening.
Use By and Batch Code are printed on label on the base of this product.
Units are packed into general-purpose case and stacked onto the pallet.

PACKAGING SPECIFICATION	
Wrap/Primary Packaging	White perforated wrap
Top Label Part Number	N/A
Bottom Label Part Number	(label change required - need bottom label part number)
Case	GP Case
Case Insert	N/A

ADDITIONAL INFORMATION
With regards to weights, there is a tolerance of +/- 5 % on an individual pack, but the average of 12 packs must meet the stated weight on the pack (convert millilitres to grams if necessary)
With regards to compliance testing for pesticides & heavy metal components, the following MAF standards are referred to:
D109 - Dairy Product Compliance **D107 - Dairy Product Safety** **D108 - Non Conforming Dairy Product**
The following MAF standard is referred to for all products: **D103 - Truth of Labelling**

Compliance with good manufacturing practice is expected when manufacturing this product

	Sign	**Date**
Technical Sign Off **Technical Manager**		
Operations Sign Off **Operations Manager**		

This specification is only valid if signed by all the above people

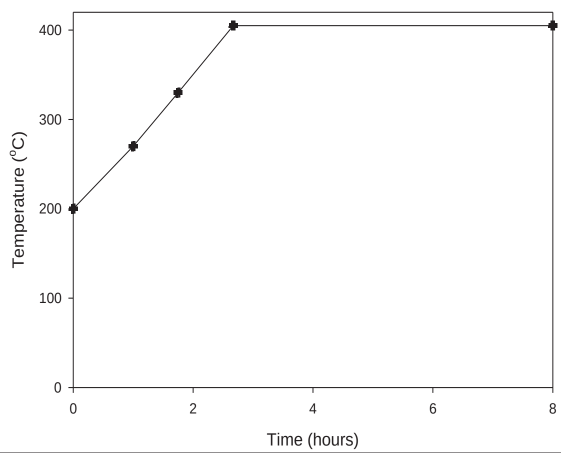
NO changes are to be made to this specification and the ingredients without PRIOR sign off by the Quality Assurance/Technical Manager

Methodology

Extended detail of Kjeldahl methodology

Two Kjeltabs were added to each digestion tube with 20mL concentrated sulphuric acid.

The samples were digested using a Tecator Digestion Unit (model: 2020). The following time/ temperature programme was applied: 0 time 200°C; 60 minutes (1.00 hours) time, 270°C; 105 minutes (1.75 hours) time 330°C; 160 to 480 minutes (2.67 to 8 hours) time 405°C, or until the samples were clear and colourless – see below



The samples were allowed to cool and 70mL of distilled water was added prior to distillation.

Automatic distillations were carried out using a Tecator Kjeltec Distilling Unit (model: 1026).

The sample was titrated against 0.1M HCl to reach a grey-mauve endpoint

Table A1: Protein determination product/ supplier list

Product	Supplier
LabServ, Analytical Grade Tri-Sodium Citrate	Biolab (Auckland, New Zealand)
LabServ, Hydrochloric Acid (32%)	Biolab (Auckland, New Zealand)
LabServ, Analytical Grade Trichloracetic Acid	Biolab (Auckland, New Zealand)
LabServ Qualitative Filter Paper (110mm)	Biolab (Auckland, New Zealand)
Foss Kjeltabs (3.5g K_2SO_4 + 3.5mg Se)	Foss Pacific (Auckland, New Zealand)
Scharlau Sulpuric Acid – 97% Reagent Grade	Global Science and Technology Ltd (Auckland, New Zealand)
AnalaR Sodium Hydroxide Pellets	Biolab (Auckland, New Zealand)
Scharlau Boric Acid, Reagent Grade	Global Science and Technology Ltd (Auckland, New Zealand)

Media Preparation Methods

Antibiotic

The antibiotic was prepared by dissolving 34mg/mL Chloramphenicol in 99.5% purity ethanol (Merck Ltd, New Zealand) and was stored at +4^{o}C until required.

Agar Preparation

All agar solutions were prepared as required. Potato Dextrose Agar (supplied by Merck Ltd, New Zealand) was made up in distilled water as per the product recommendations (39g/L) and was brought to the boil on a hot plate using a magnetic stirrer to completely dissolve the agar. The agar was autoclaved using an Anstell Scientific (model 901 – 162) at 121 ± 1^{o}C for 2.5 hours. Following cooling 25µg/mL antibiotic solution was added to the agar and mixed using a magnetic stirrer for 5 minutes. The required number of plates were aseptically poured in a Heraues Sterile Cabinet (model HS18) and stored in a chiller set to 4 ± 2^{o}C until required.

Peptone Water Preparation

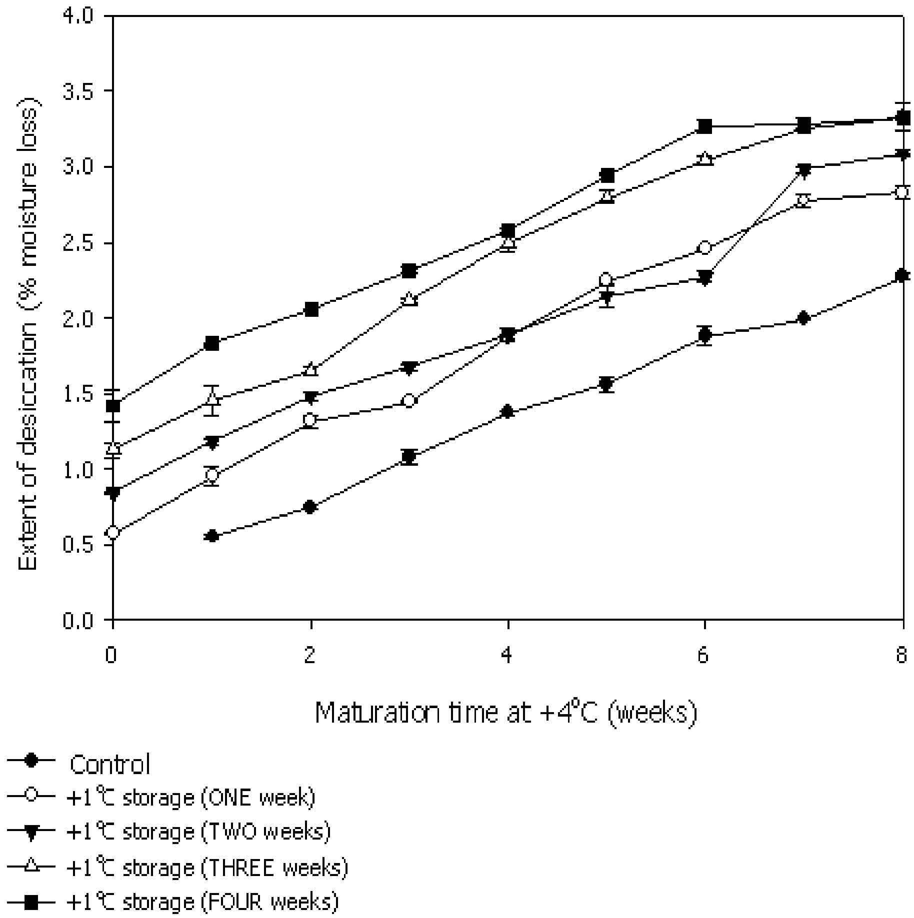
All peptone water was prepared daily, as required. Solutions were made up using 0.1% Universal Peptone M66 (Merck Ltd, New Zealand) (w/v) in distilled water and mixed thoroughly using a magnetic stirrer for 5 minutes. The peptone solution was autoclaved using an Anstell Scientific (model 901 – 162) at 121 ± 1^{o}C for 2.5 hours and stored in the chiller at 4 ± 2^{o}C until required.

Table A2: Yeast and Mould enumeration product/ supplier list

Product	Supplier
Chloramphenicol Selective Supplement	Sigma Aldrich Pty Ltd. (Auckland, New Zealand)
Ethanol (99.5% purity)	Merck Ltd. (Auckland, New Zealand)
Potato Dextrose Agar	Merck Ltd. (Auckland, New Zealand)
Universal Peptone M66	Merck Ltd. (Auckland, New Zealand)

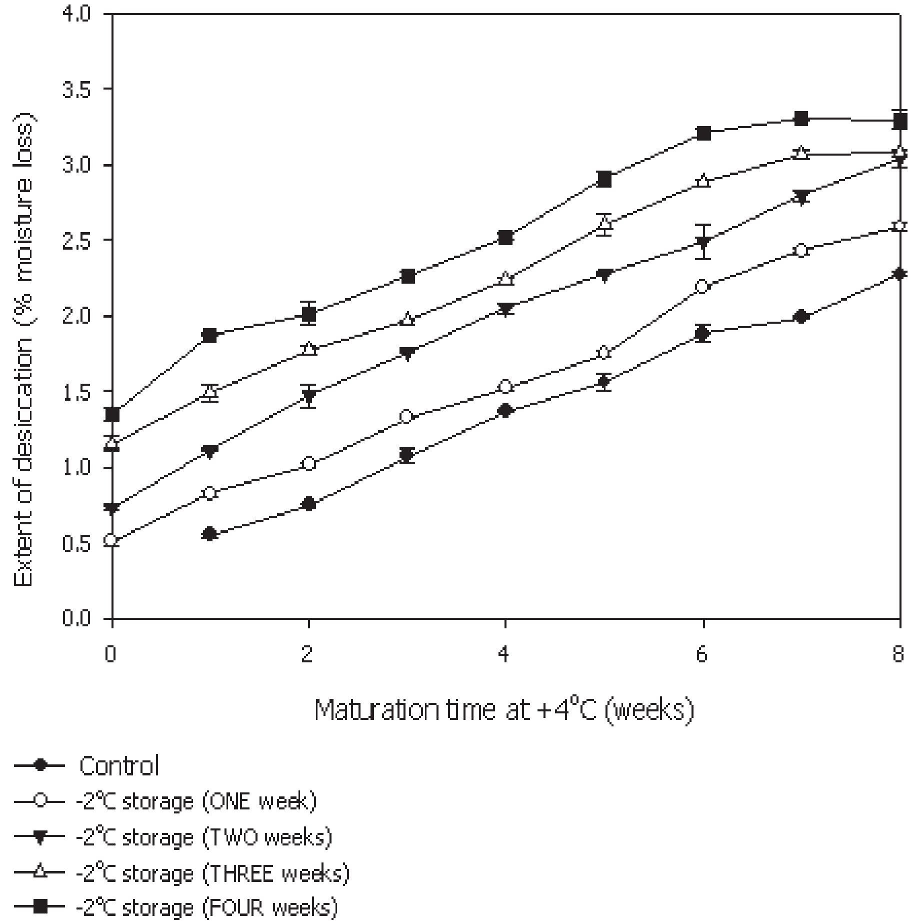
Stage ONE trial results

Moisture content



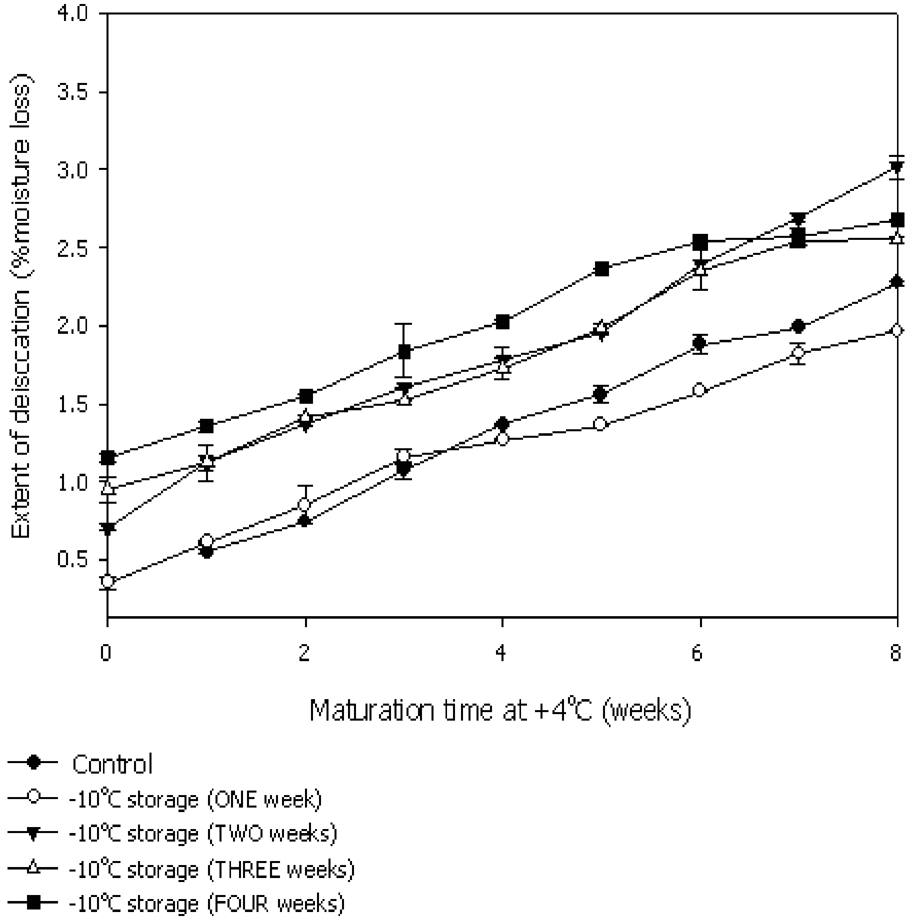
Each data point is representative of an average of duplicate samples ± standard error.

Figure A1: Moisture loss (%) in wrapped Camembert cheese samples throughout maturation at +4°C following storage at +1°C for ZERO, ONE, TWO, THREE and FOUR weeks



Each data point is representative of an average of duplicate samples ± standard error.

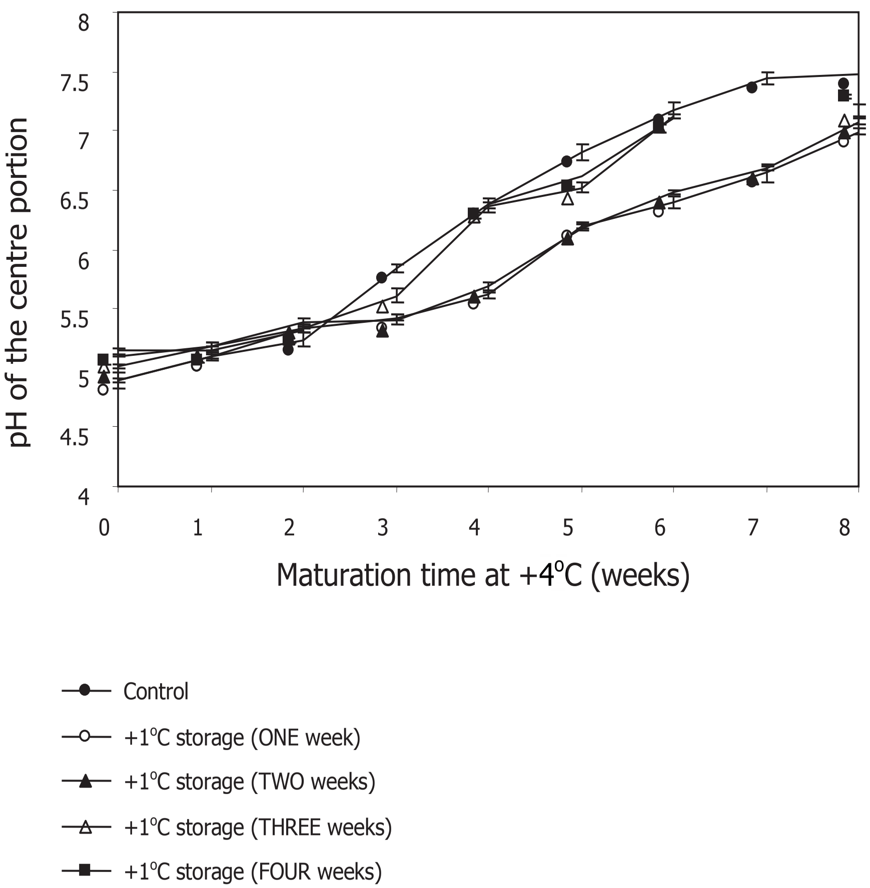
Figure A2: Moisture loss (%) in wrapped Camembert cheese samples throughout maturation at +4°C following storage at -2°C for ZERO, ONE, TWO, THREE and FOUR weeks



Each data point is representative of an average of duplicate samples ± standard error.

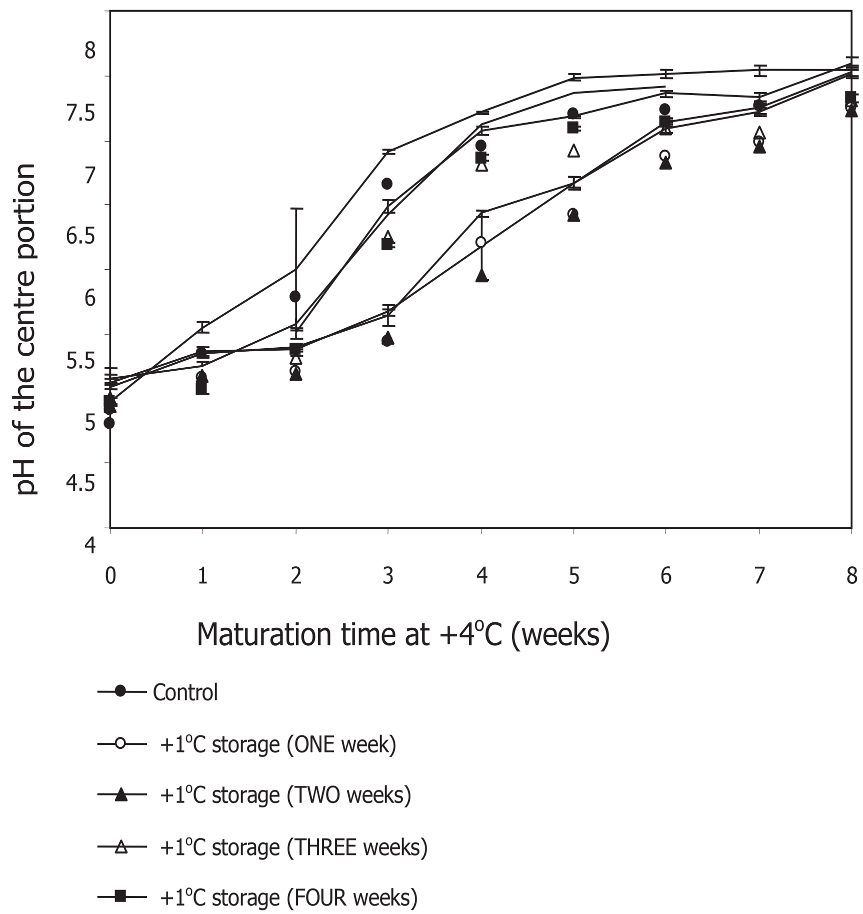
Figure A3: Moisture loss (%) in wrapped Camembert cheese samples throughout maturation at +4°C following storage at -10°C for ZERO, ONE, TWO, THREE and FOUR weeks

pH



Results are representative of an average of duplicate measurements ± standard error

Figure A4: Change in pH of the centre portion of Camembert cheese throughout maturation at +4°C, following storage at +1°C for ZERO, ONE, TWO, THREE and FOUR weeks



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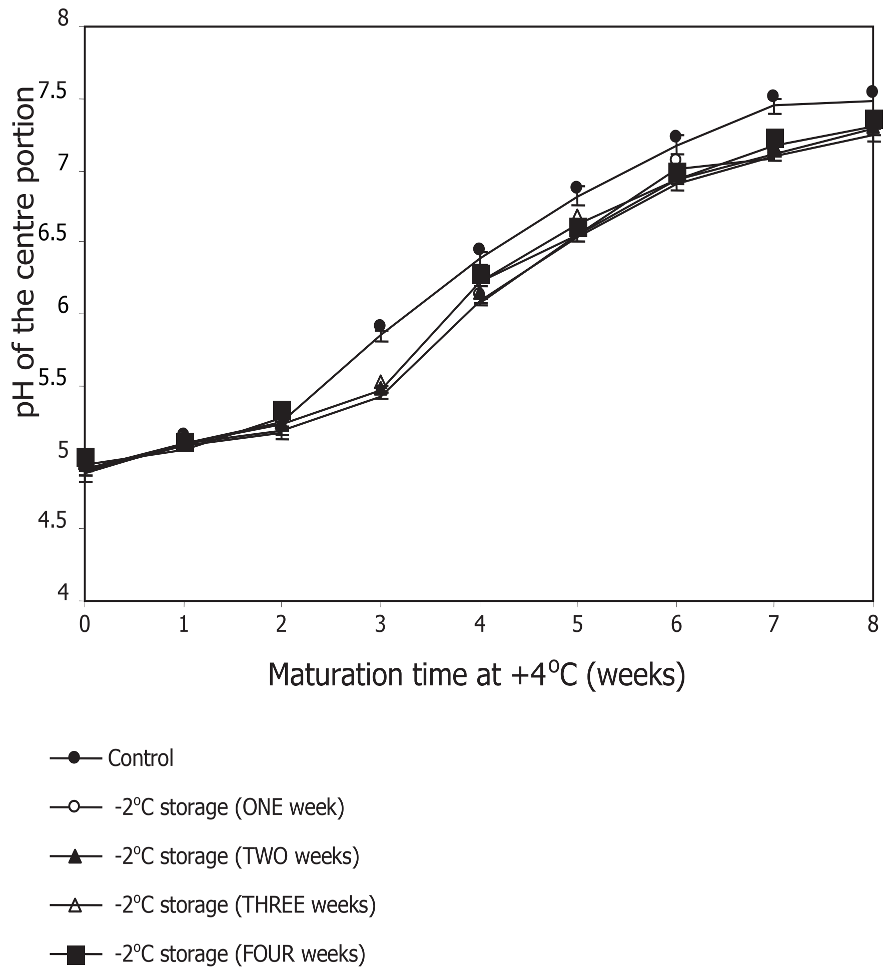
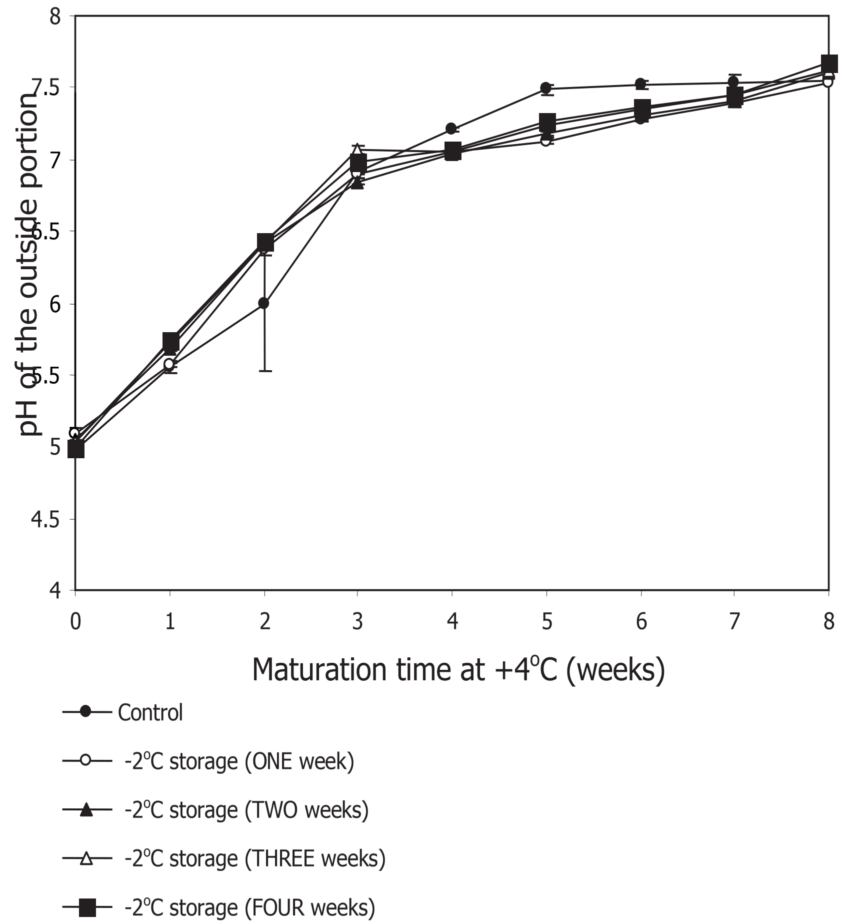
Results are representative of an average of duplicate measurements ± standard error

Figure A5: Change in the pH of the outside portion of Camembert cheese throughout maturation at +4°C, following storage at +1°C for ZERO, ONE, TWO, THREE and FOUR weeks



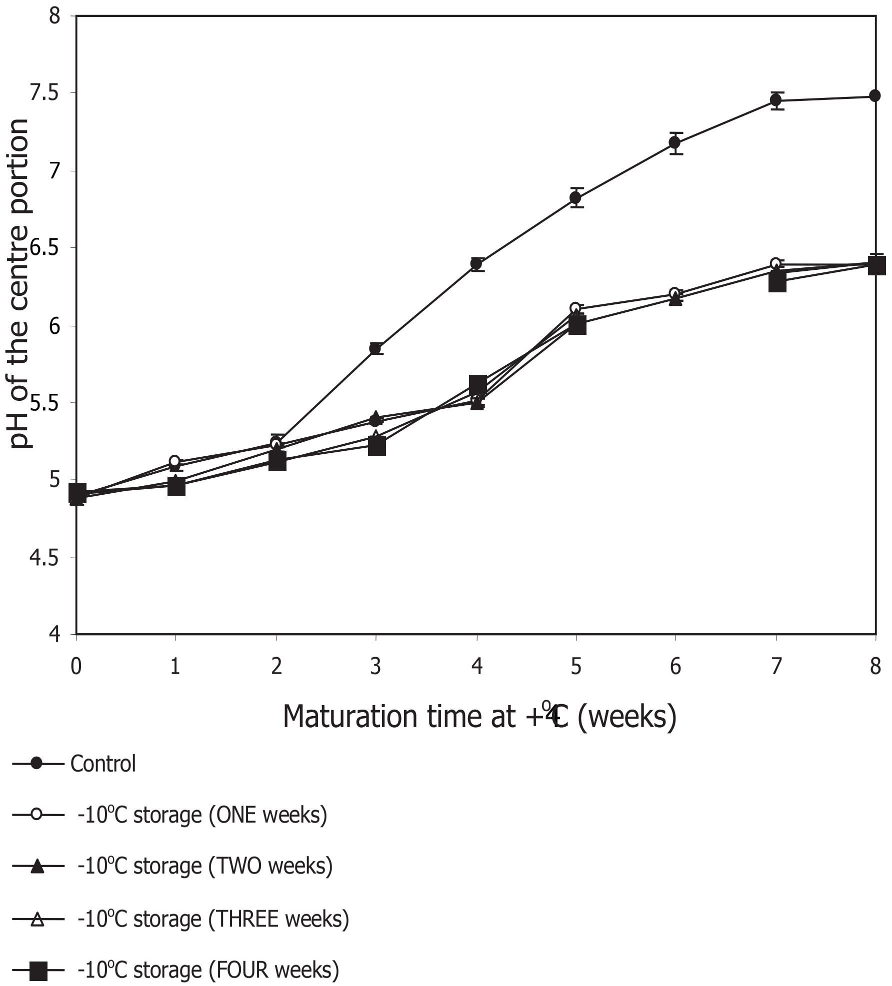
Results are representative of an average of duplicate measurements ± standard error

Figure A6: Change in pH of the centre portion of Camembert cheese throughout maturation at +4°C, following storage at -2°C for ZERO (control), ONE, TWO, THREE and FOUR weeks



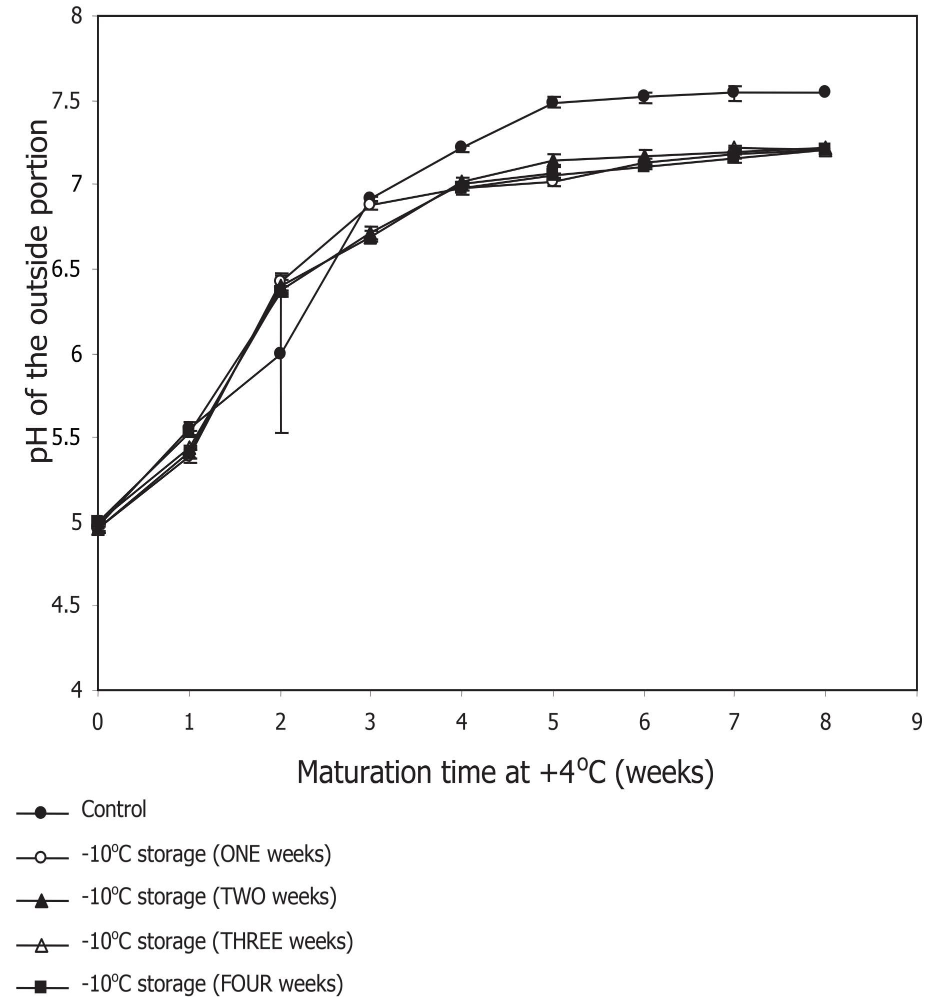
Results are representative of an average of duplicate measurements ± standard error

Figure A7: Change in pH of the outside portion of Camembert cheese throughout maturation at +4°C, following storage at -2°C for ZERO (control), ONE, TWO, THREE and FOUR weeks



Results are representative of an average of duplicate measurements ± standard error

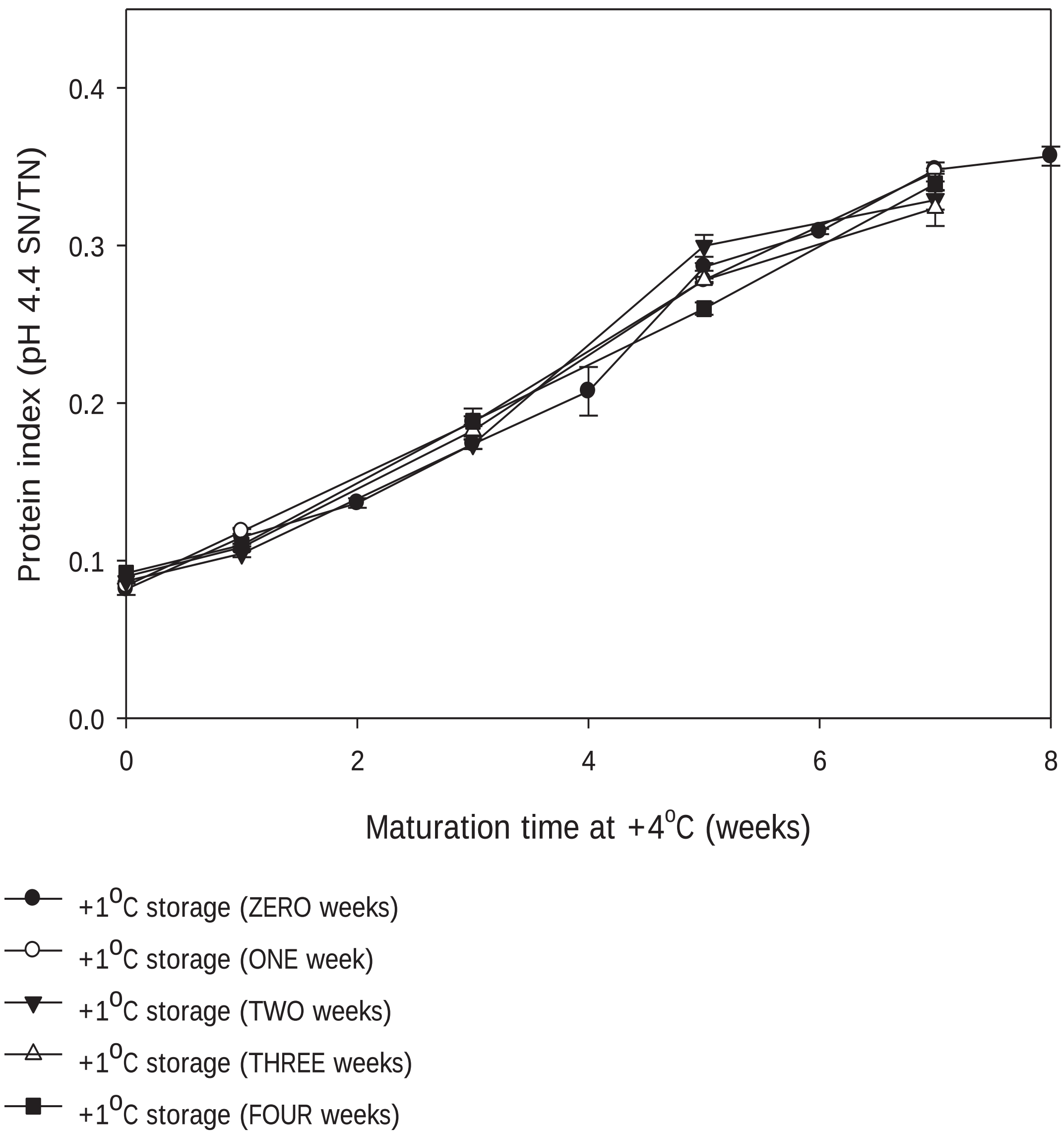
Figure A8: Change in pH of the centre portion of Camembert cheese throughout maturation at +4°C, following storage at -10°C for ONE, TWO, THREE and FOUR weeks



Results are representative of an average of duplicate measurements ± standard error

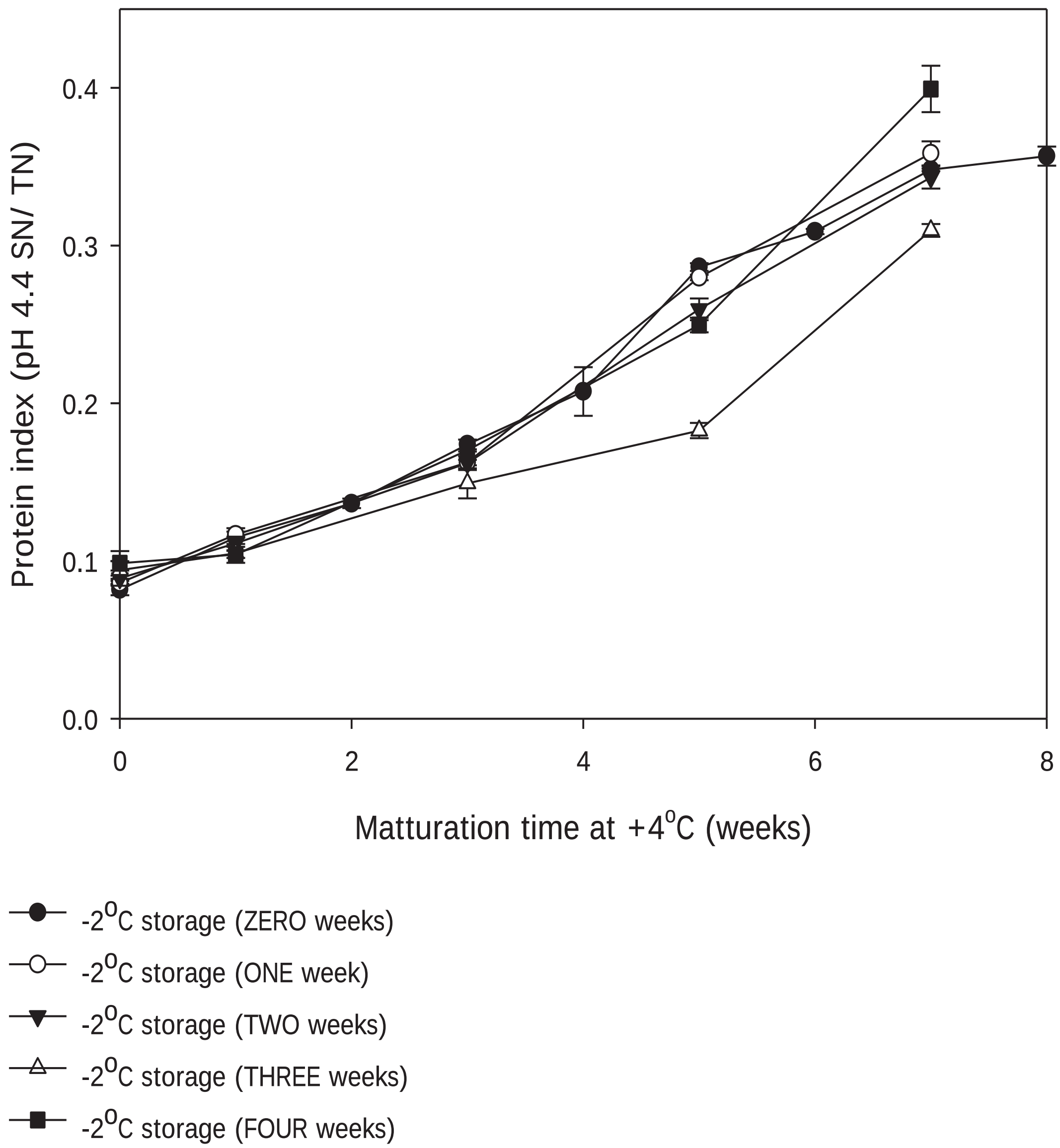
Figure A9: Change in the pH of the outside portion of Camembert cheese throughout maturation at +4°C, following storage at -10°C for ZERO, ONE, TWO, THREE and FOUR weeks

Protein index (pH 4.4 SN/TN)



Results are representative of an average of duplicate assay measurements ± standard error.

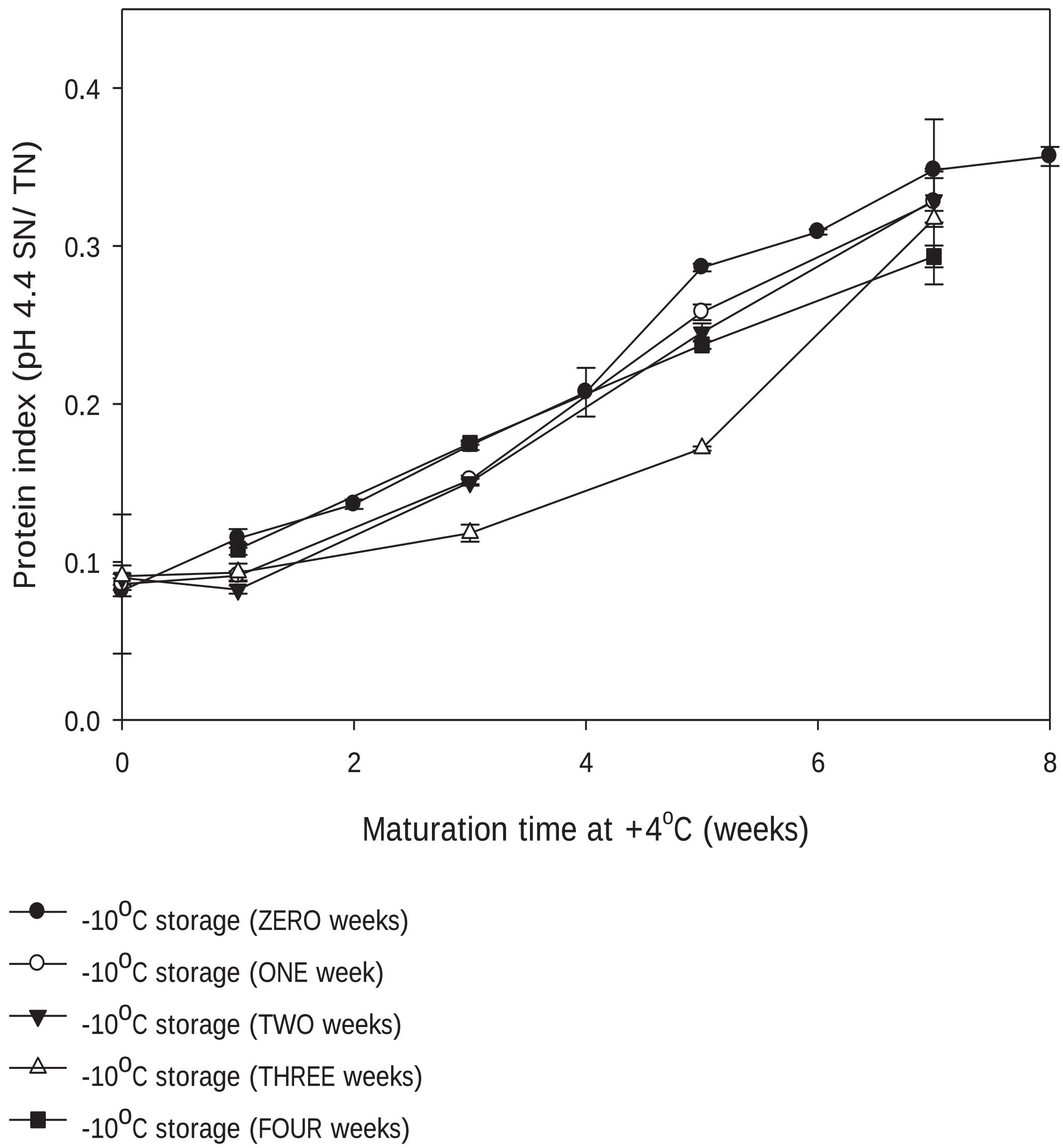
Figure A10: Change in the proteolysis index (pH 4.4 SN/ TN) in Camembert cheese during maturation at +4°C following storage at +1°C for ZERO, ONE, TWO, THREE and FOUR weeks



-

Results are representative of an average of duplicate assay measurements ± standard error.

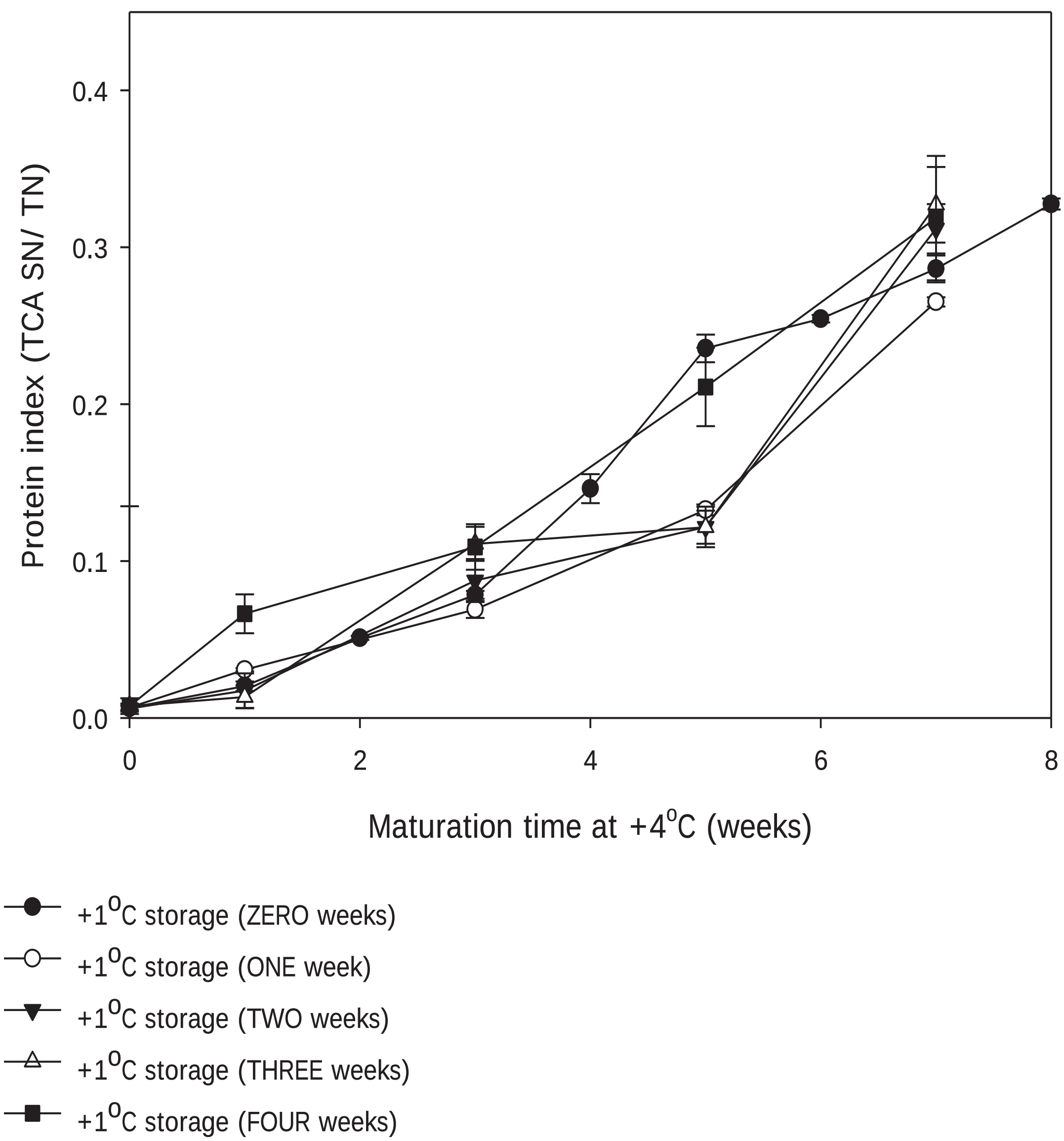
Figure A11: Change in the proteolysis index (pH 4.4 SN/ TN) in Camembert cheese during maturation at +4°C following storage at -2°C for Control, ONE, TWO, THREE and FOUR weeks



Results are representative of an average of duplicate assay measurements ± standard error.

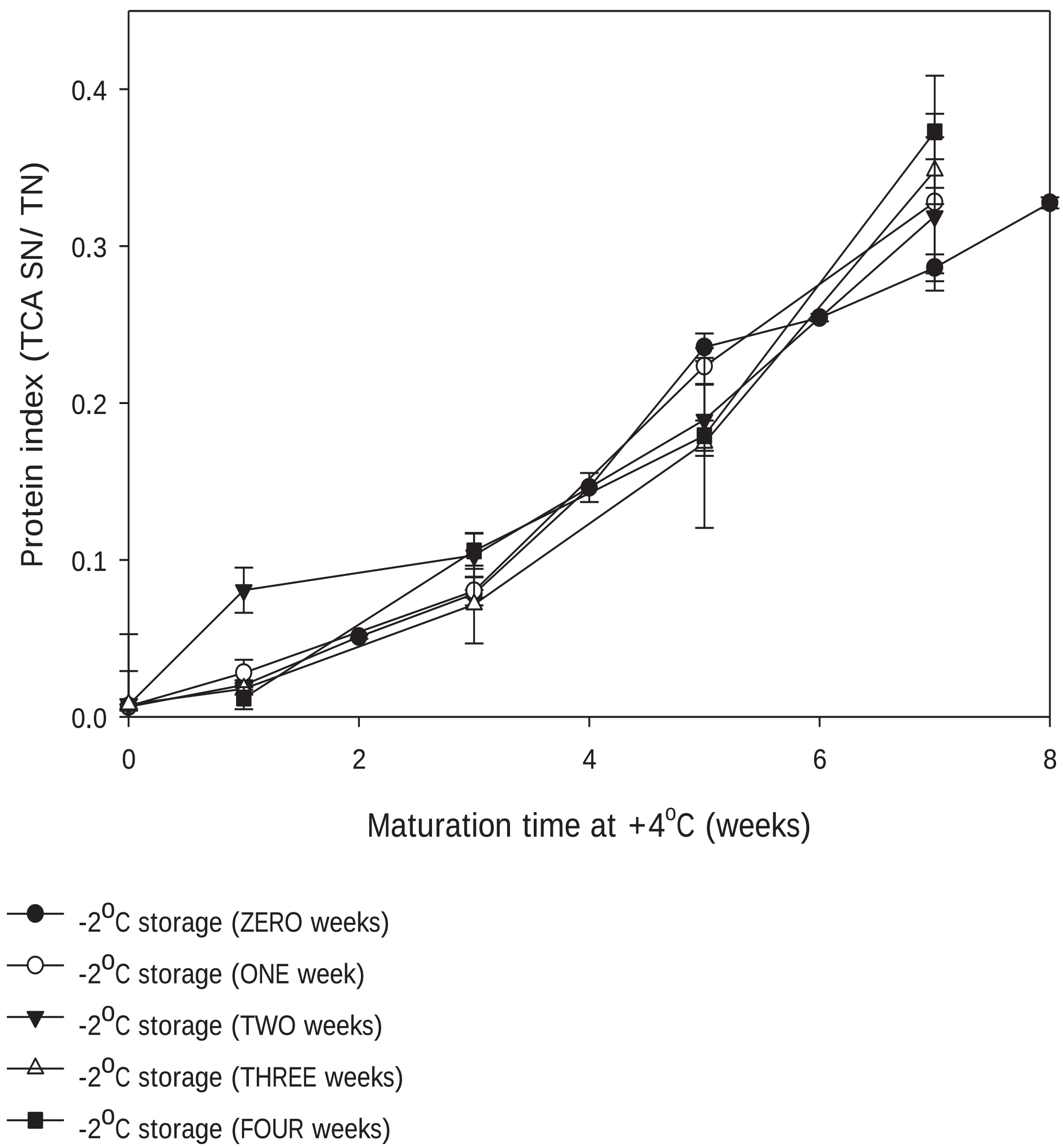
Figure A12: Change in the proteolysis index (pH 4.4 SN/ TN) in Camembert cheese during maturation at +4°C following storage at -10°C for Control, ONE, TWO, THREE and FOUR weeks

Protein index (TCA SN/ TN)



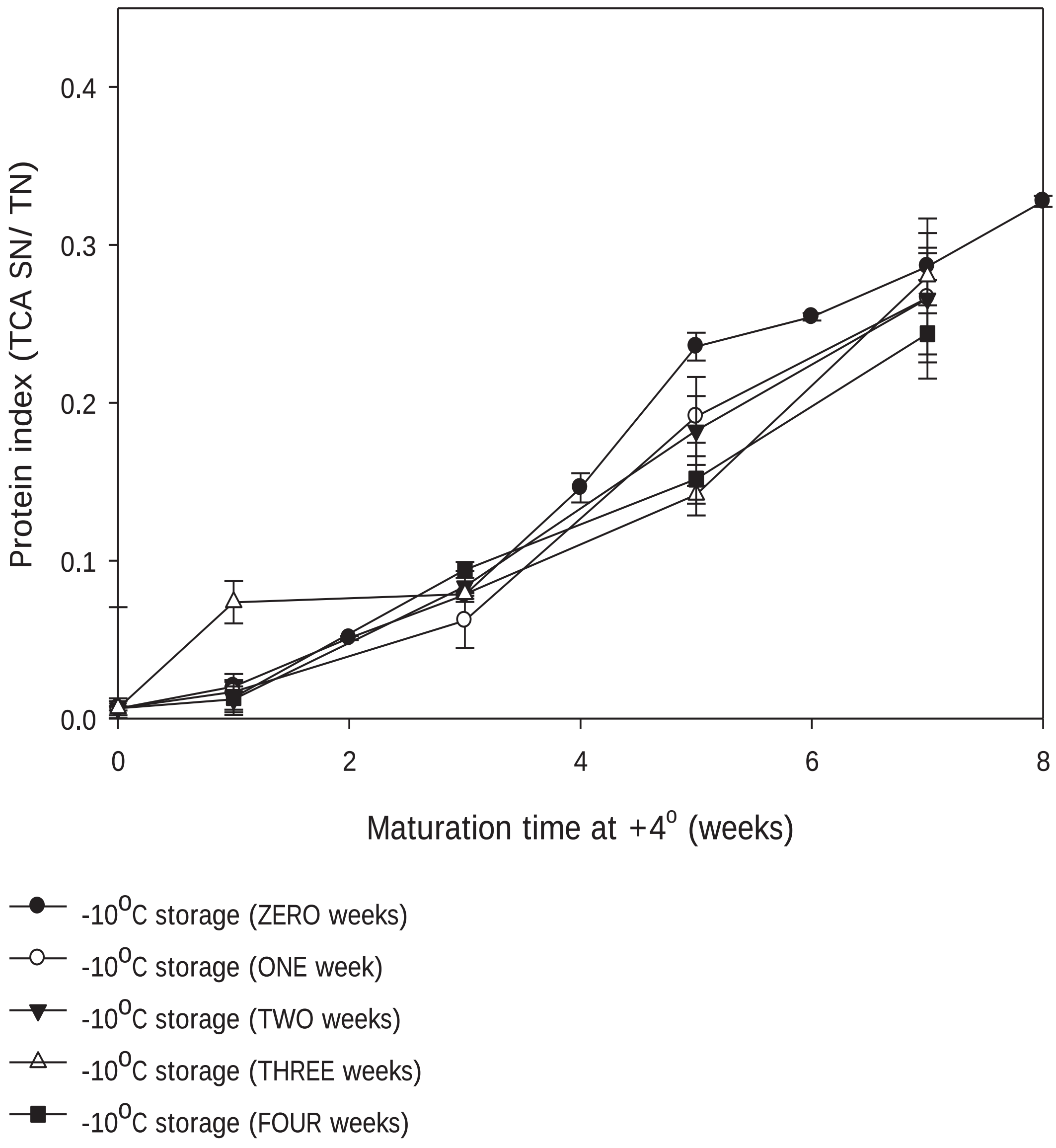
Results are representative of an average of duplicate assay measurements ± standard error.

Figure A13: Change in the proteolysis index (TCA SN/ TN) in Camembert cheese throughout maturation at +4°C following storage at +1°C for ZERO (Control), ONE, TWO, THREE and FOUR weeks



Results are representative of an average of duplicate assay measurements ± standard error.

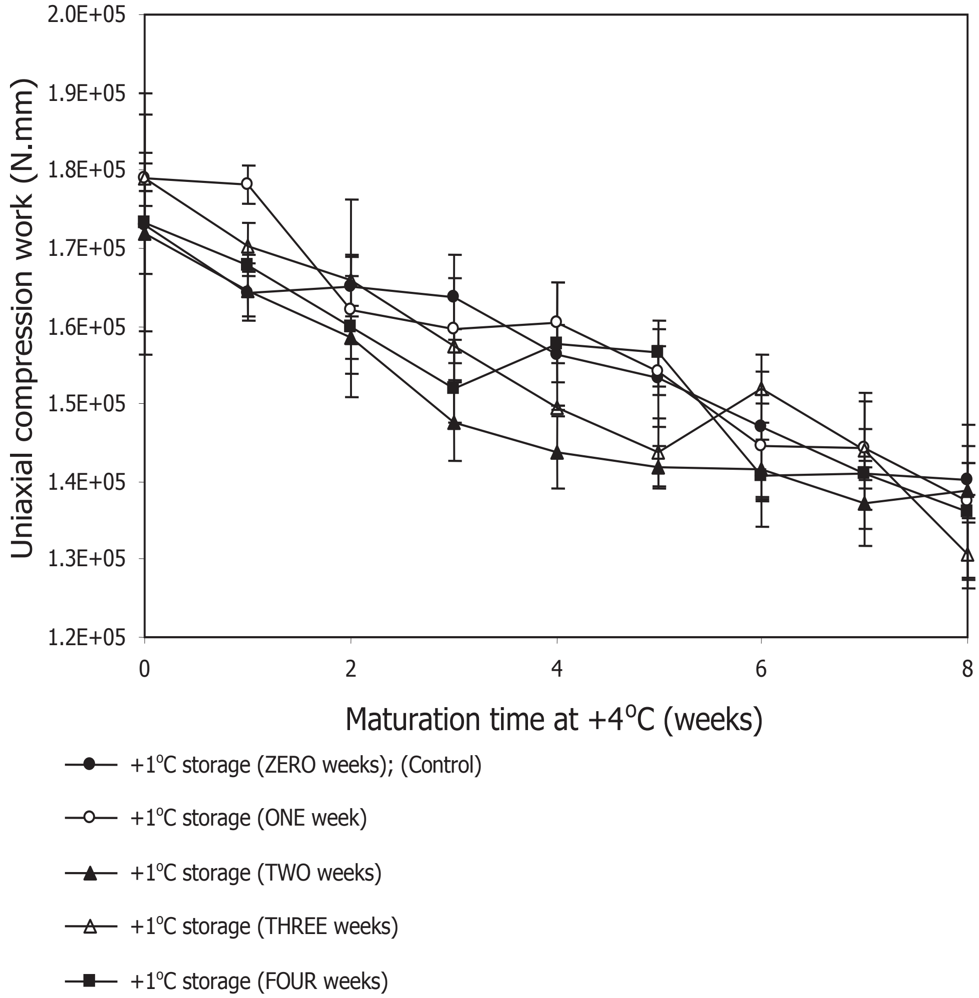
Figure A6.14: Change in the proteolysis index (TCA SN/ TN) in Camembert cheese throughout maturation at +4^{o}C following storage at -2^{o}C for ZERO, ONE, TWO, THREE and FOUR weeks



Results are representative of an average of duplicate assay measurements ± standard error.

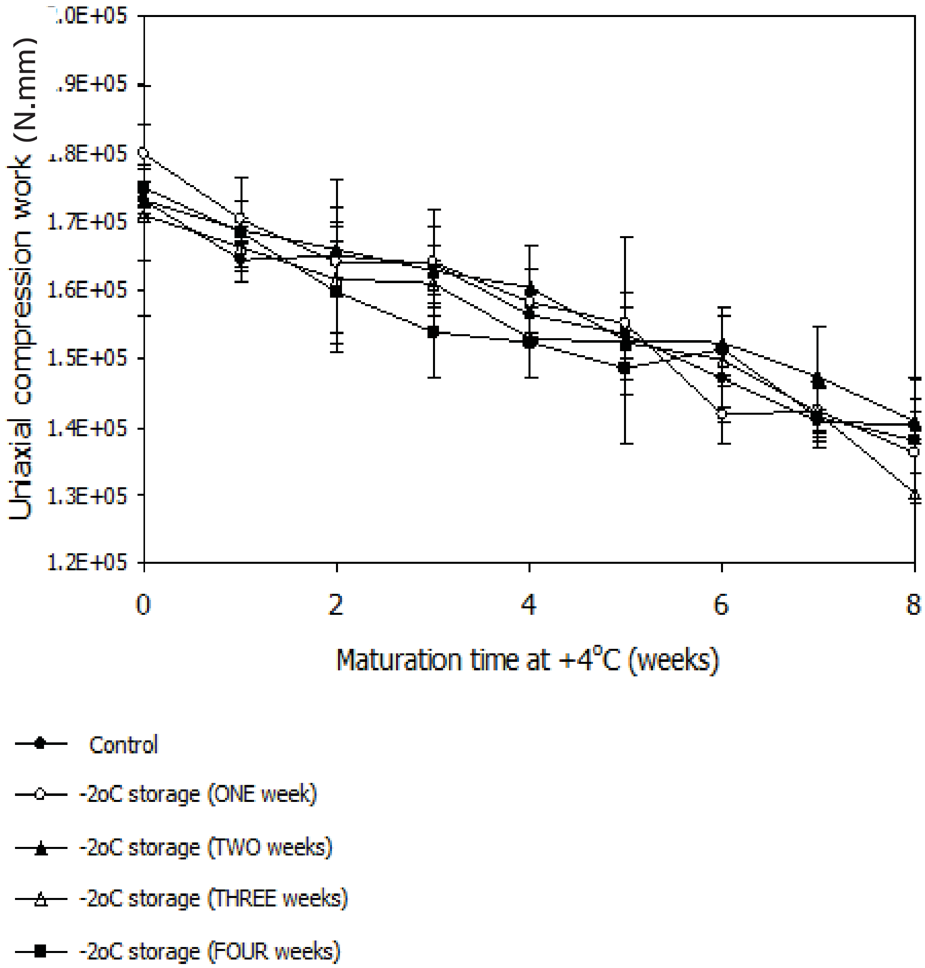
Figure A15: Change in the proteolysis index (TCA SN/ TN) in Camembert cheese throughout maturation at +4°C following storage at -10°C for ZERO (Control), ONE, TWO, THREE and FOUR weeks

Uniaxial compression



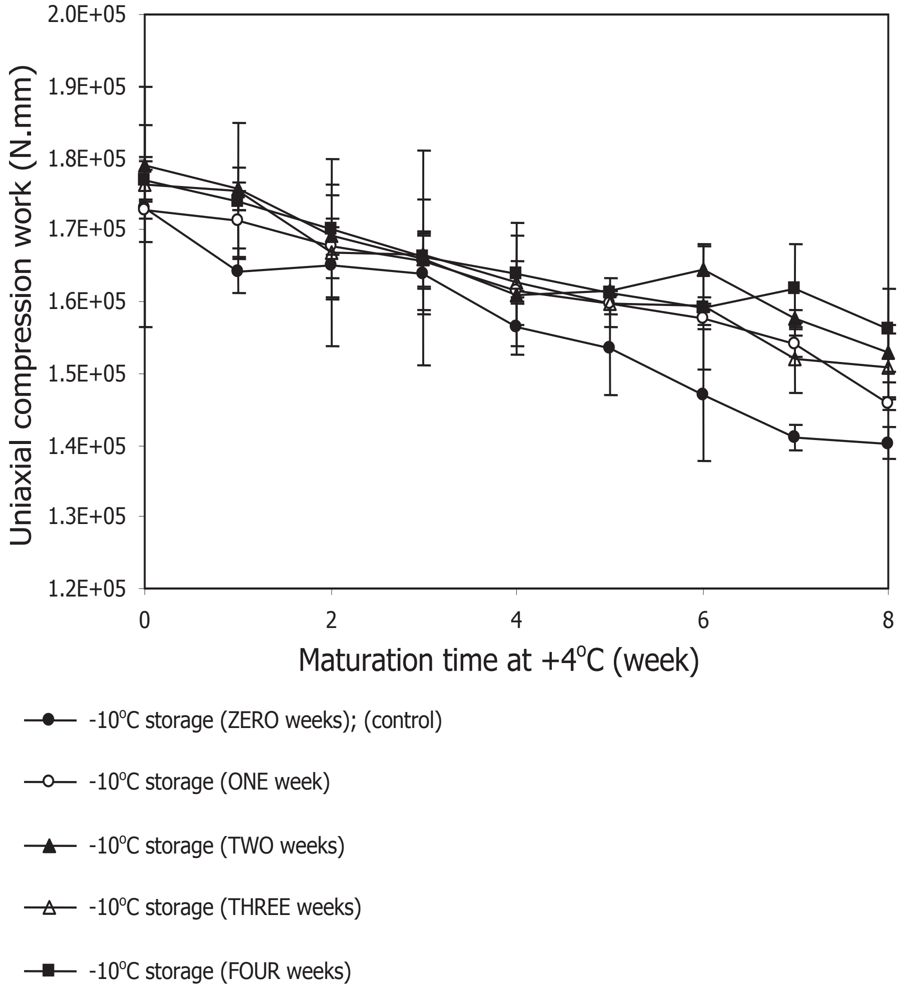
Results are indicative of an average of quadruplet samples ± standard error

Figure A16: Change in the uniaxial compression work required to compress Camembert cheese samples to 80% of the original height throughout maturation at +4°C following storage at +1°C for ZERO (Control), ONE, TWO, THREE and FOUR weeks



Results are indicative of an average of quadruplet samples ± standard error

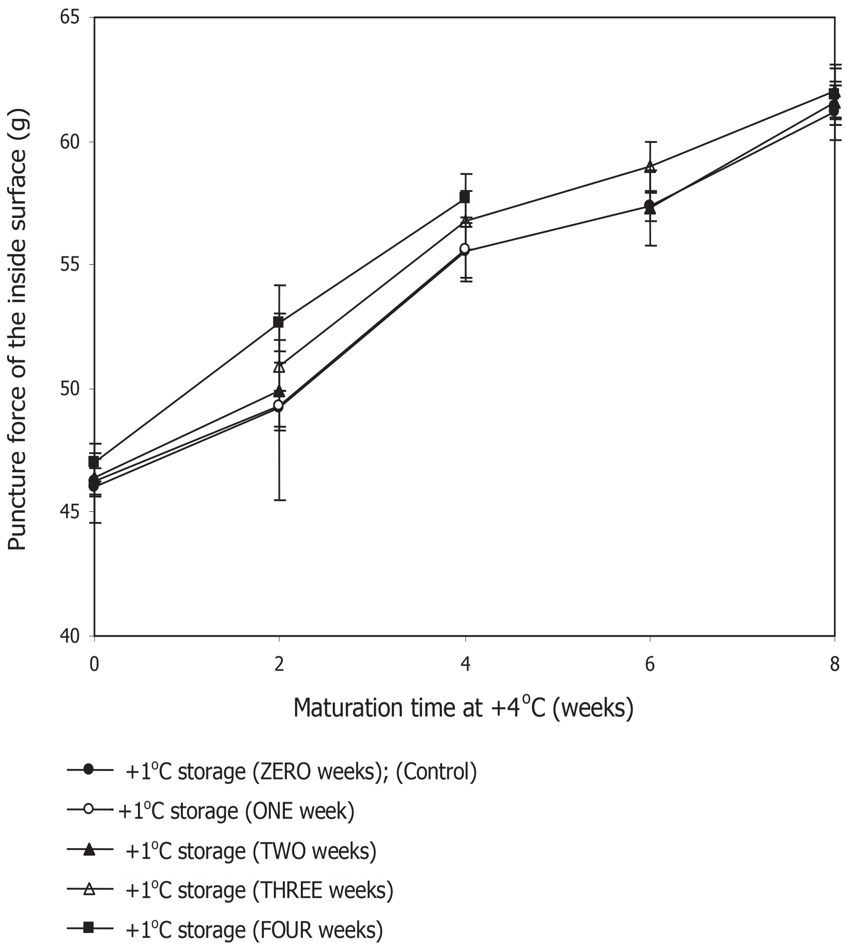
Figure A17: Change in the uniaxial compression work required to compress Camembert cheese samples to 80% of the original height throughout maturation at +4^{o}C following storage at -2^{o}C for ZERO, ONE, TWO, THREE and FOUR weeks



Results are indicative of an average of quadruplet samples ± standard error

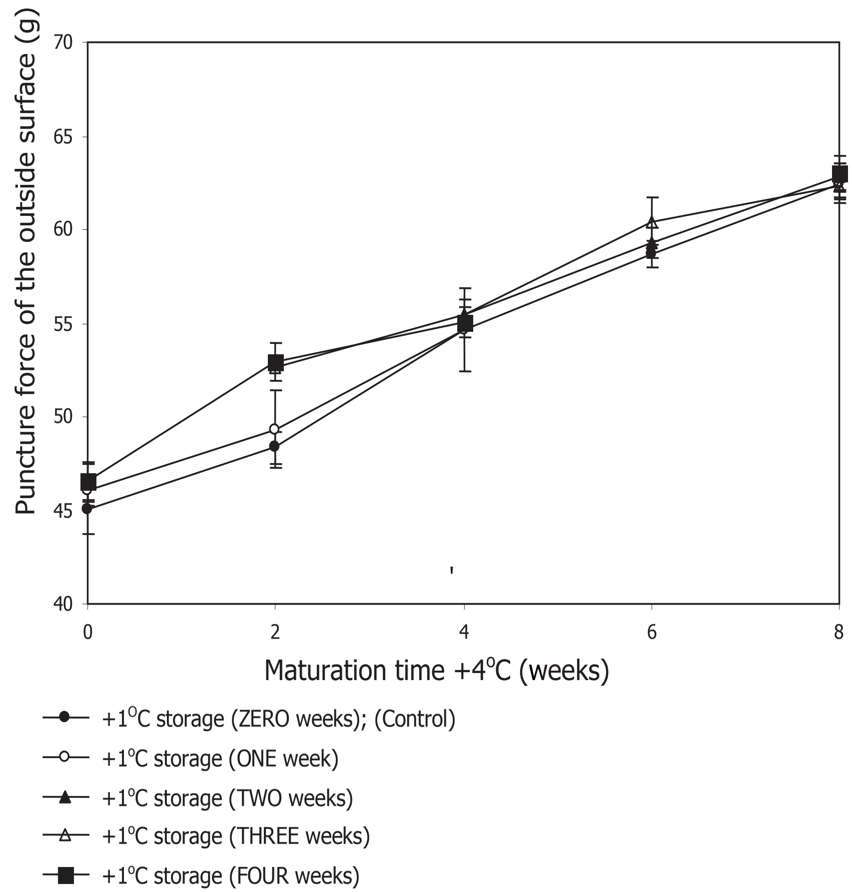
Figure A18: Change in the uniaxial compression work required to compress Camembert cheese samples to 80% of the original height throughout maturation at +4°C following storage at -10°C for ZERO (control), ONE, TWO, THREE and FOUR weeks

Puncture testing



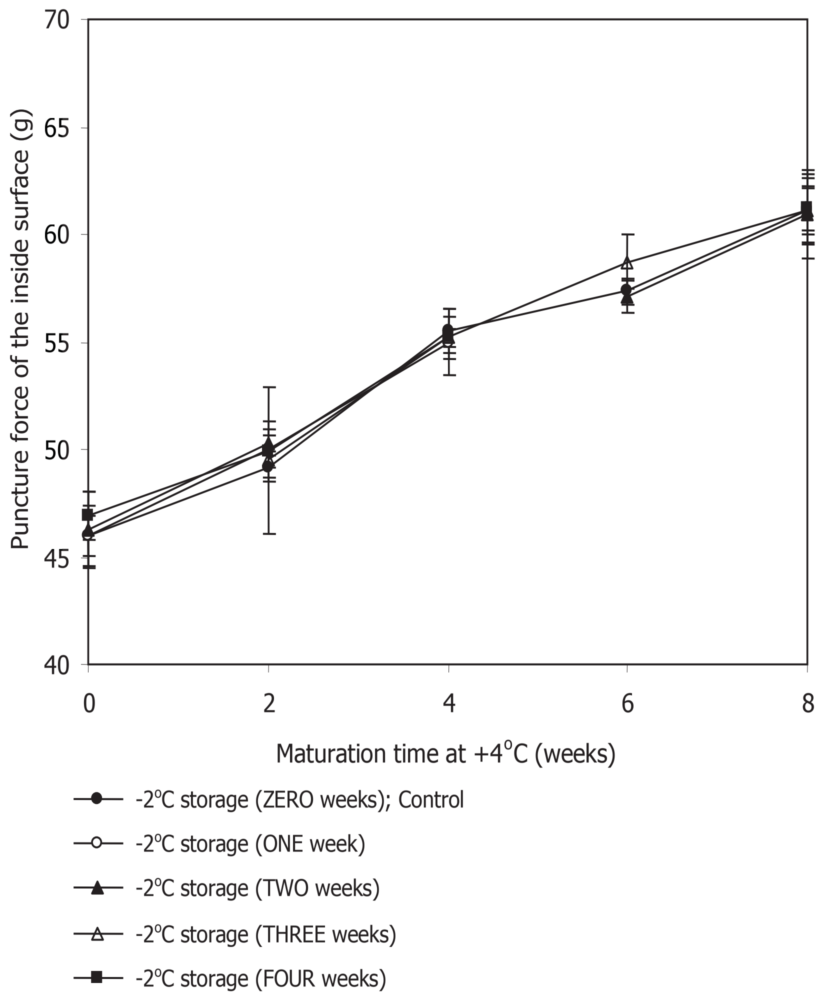
Results are representative of an average of 15 punctures in duplicate samples ± standard error

Figure A19: Change in the force required to puncture the surface of Camembert cheese during maturation at +4oC following storage at +1oC for ZERO (control), ONE, TWO, THREE and FOUR weeks (inside diameter of each unit of cheese)



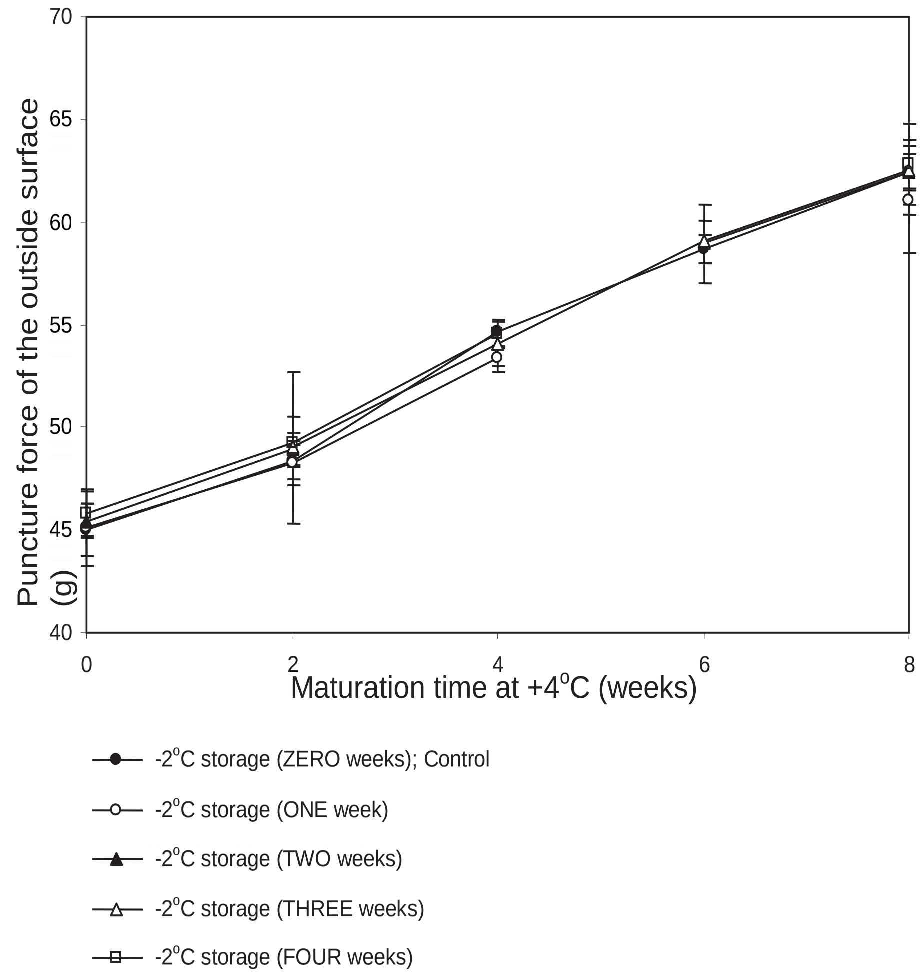
Results are representative of an average of 15 punctures in duplicate samples ± standard error

Figure A20: Change in the force required to puncture the surface of Camembert cheese during maturation at +4oC following storage at +1oC for ZERO (control), ONE, TWO, THREE and FOUR weeks (outside diameter of each unit of cheese)



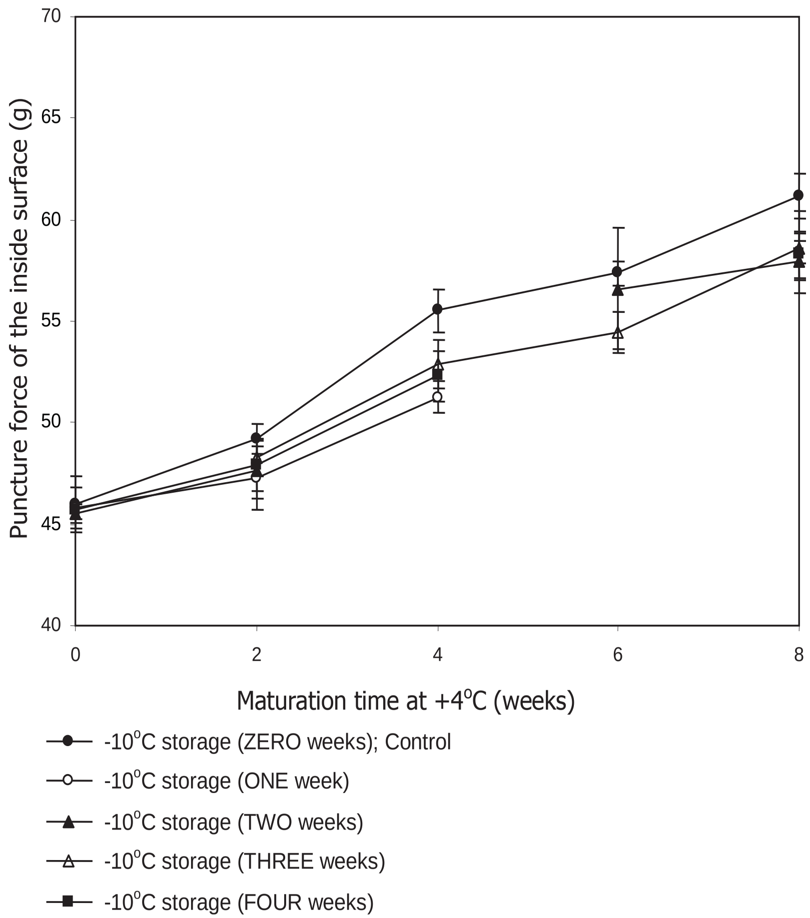
Results are representative of an average of 15 punctures in duplicate samples ± standard error

Figure A21: Change in the force required to puncture the inside surface of Camembert cheese during maturation at +4°C following storage at -2°C for ZERO (control), ONE, TWO, THREE and FOUR weeks (inside diameter of each unit of cheese)



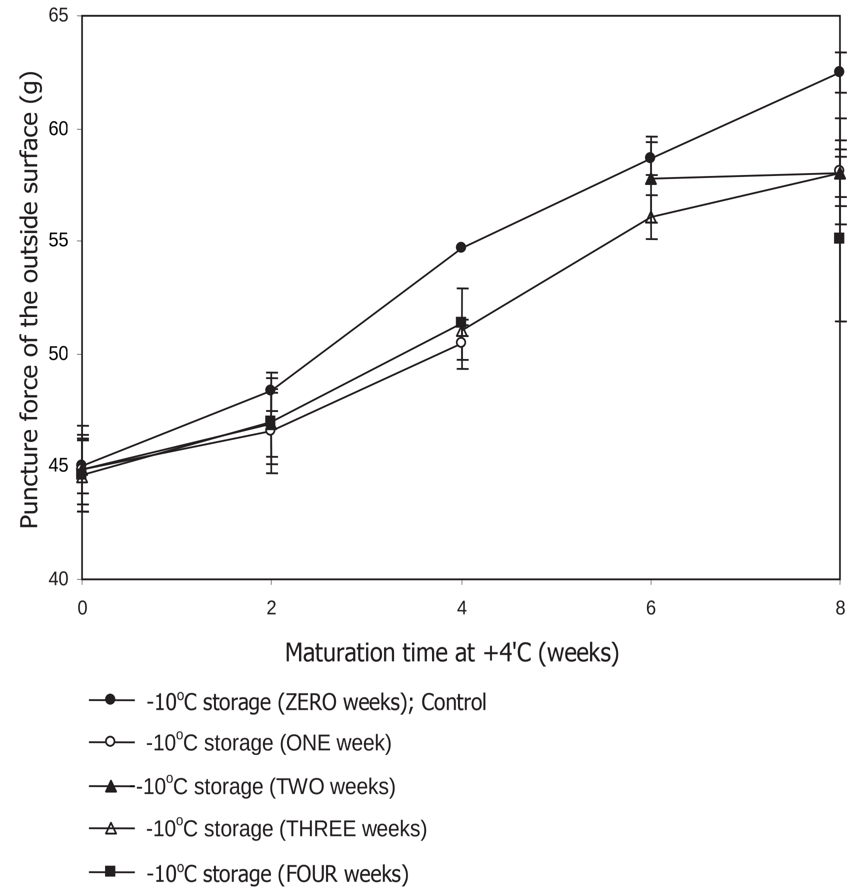
Results are representative of an average of 15 punctures in duplicate samples ± standard error

Figure A22: Change in the force required to puncture the outside surface of Camembert cheese during maturation at +4°C following storage at -2°C for ZERO (control), ONE, TWO, THREE and FOUR weeks (outside diameter of each unit of cheese)



Results are representative of an average of 15 punctures in duplicate samples ± standard error

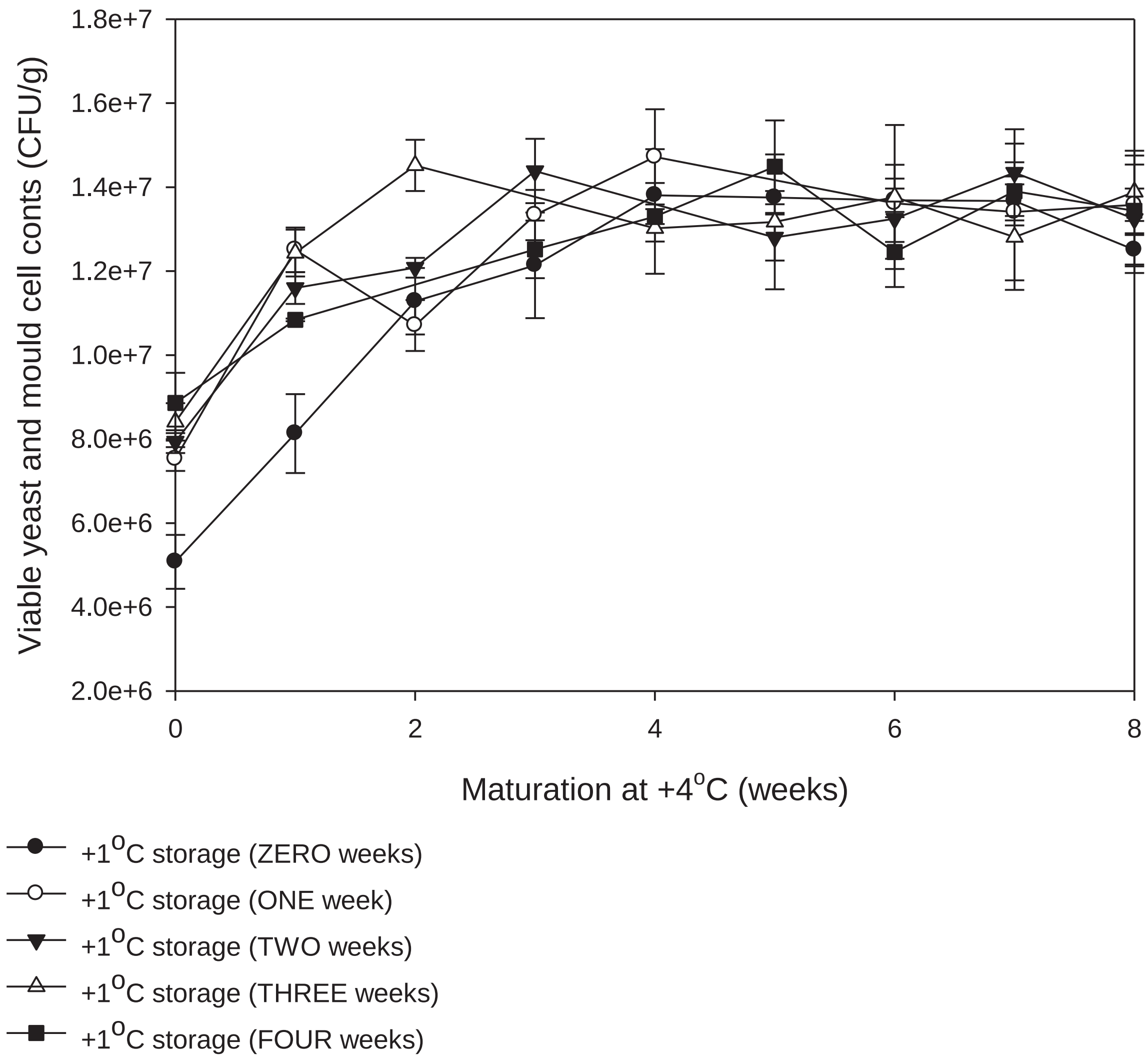
Figure A23: Change in the force required to puncture the inside surface of Camembert cheese during maturation at +4°C following storage at -10°C for ZERO (control), ONE, TWO, THREE and FOUR weeks (inside diamter of each unit of cheese)



Results are representative of an average of 15 punctures in duplicate samples ± standard error

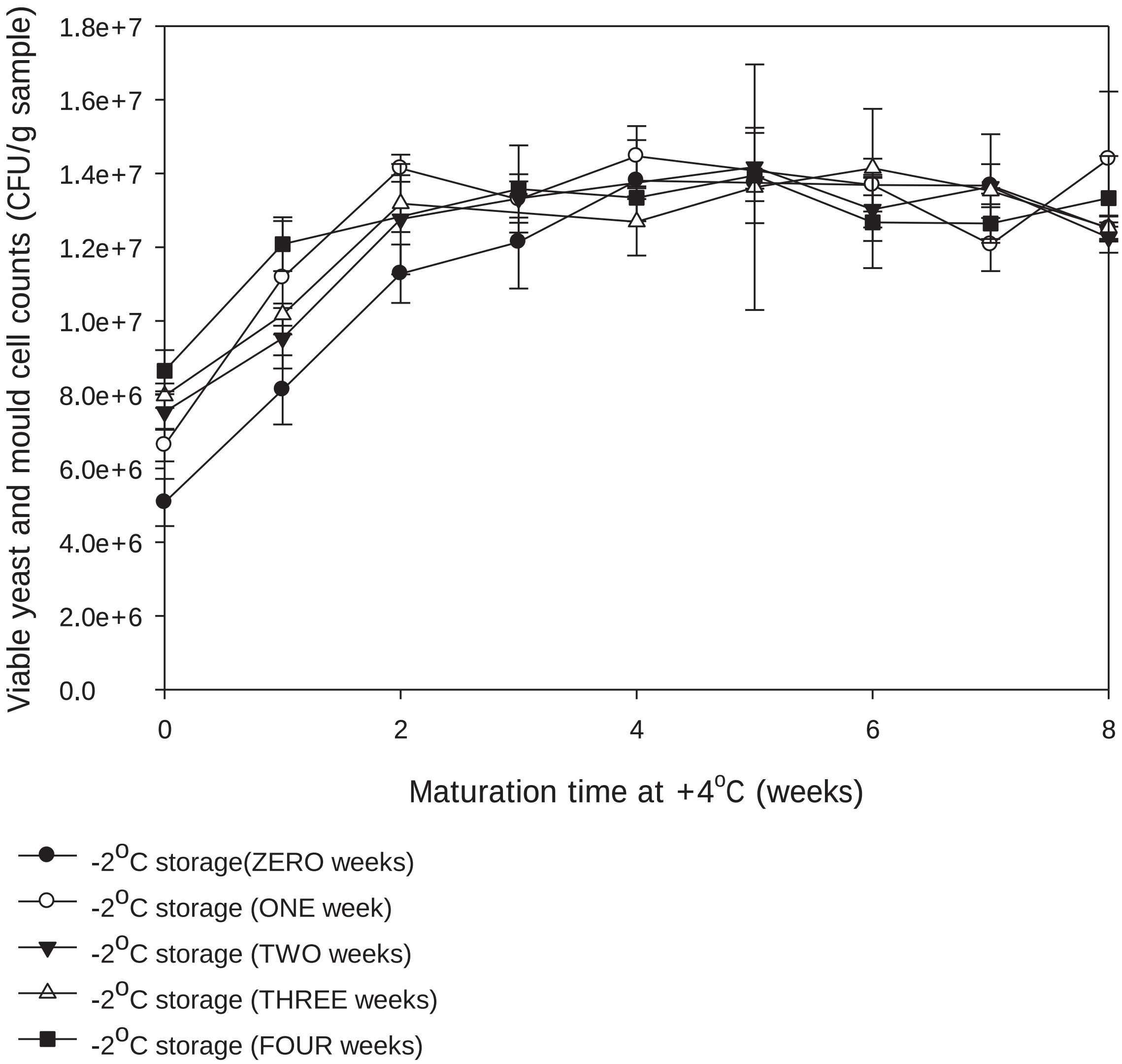
Figure A24: Change in the force required to puncture the outside surface of Camembert cheese during maturation at +4°C following storage at -2°C for ZERO (control), ONE, TWO, THREE and FOUR weeks (inside diameter of each unit of cheese)

Yeast and mould enumeration



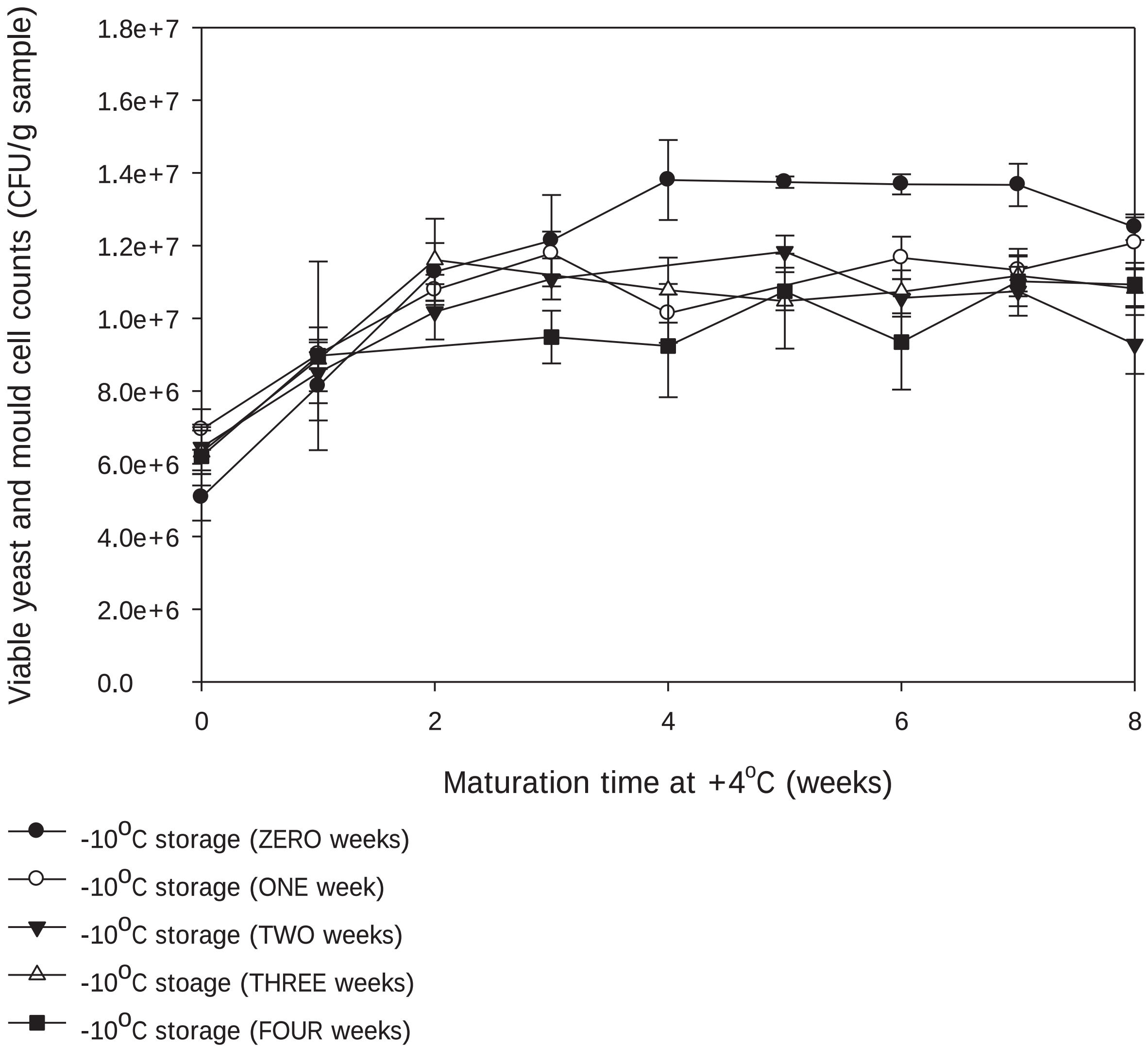
Results are representative of an average of duplicate assay measurements ± standard error.

Figure A25: Change in viable yeast and mould cell counts on the surface of Camembert cheese during maturation at +4°C following storage at +1°C for ZERO, ONE, TWO, THREE and FOUR weeks



Results are representative of an average of duplicate assay measurements ± standard error.

Figure A26: Change in viable yeast and mould cell counts on the surface of Camembert cheese during maturation at +4°C following storage at -2°C for ZERO, ONE, TWO, THREE and FOUR weeks



Results are representative of an average of duplicate assay measurements ± standard error.

Figure A27: Change in viable yeast and mould cell counts on the surface of Camembert cheese during maturation at +4°C following storage at -10°C for ZERO, ONE, TWO, THREE and FOUR weeks

T-test results; mean difference from control for each time: temperature treatment

Table A3: Results of the two-tailed t-test for mean difference from the control at the 99% level of significance

Control average throughout maturation	*Moisture*	*pH inside*	*pH outside*	*pH 4.4 SN*	*TCA SN*	*Uniaxial*	*Puncture - inside*	*Puncture outside*	*Enumeration of Yeast and moulds*
	1.048968	5.921786	6.5228571	0.187115	0.113154	157947.4	53.84522	53.83019143	1144232
+1°C storage (ONE weeks)	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD
+1°C storage (TWO weeks)	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD
-+1°C storage (THREE weeks)	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD
+1°C storage (FOUR weeks)	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD
-2°C storage (ONE weeks)	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD
-2°C storage (TWO weeks)	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD
-2°C storage (THREE weeks)	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD
-2°C storage (FOUR weeks)	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD
-10°C storage (ONE weeks)	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD
-10°C storage (TWO weeks)	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD
-10°C storage (THREE weeks)	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD
-10°C storage (FOUR weeks)	NSD	NSD	NSD	NSD	NSD	158649 < 166623 < 174597	NSD	NSD	7088202 < 9287854 < 11437507

NSD = no significant difference

Stage TWO trial results

Consent form

Massey University
Te Kunenga ki Pūrehuroa

Sensory Evaluation of Camembert Cheese

Researcher(s) Introduction

Researchers Name:	Shannon Swan	Supervisors Name:	Dr. Marie Wong
Contact Details:	Shannon.L.Swan@gmail.com	Contact Details:	m.wong@massey.ac.nz

You are invited to take part in a consumer sensory evaluation to determine the acceptability of camembert cheese.

Your participation in this activity will take approximately 10 minutes.

We are selecting people for this exercise who would typically consume camembert cheese more than once per year.

The samples you will be tasting contain the following components that can be harmful or cause allergic reactions with certain groups of people (delete those not contained in the foods in question). You are requested not to partake if you may be adversely affected by the following:

- *Milk* and *milk* derivatives
- May contain traces of *nuts* and *sesame seed* and *peanuts* and derivatives

The information collected in this study will be used to complete an assignment in partial fulfilment of the Masters of Technology in Food Technology. No data linked to an individual's identity will be collected.

If you have any questions about this work, please contact one of the people indicated above.

This project has been reviewed and approved by the Massey University Human Ethics Committee, PN Protocol HEC: PN Protocol 03/34*)*. If you have any concerns about the conduct of this research, please contact Professor Sylvia V Rumball, Chair, Massey University Campus Human Ethics Committee: Palmerston North, telephone 06 350 5249, email S.V.Rumball@massey.ac.nz.

THIS CONSENT FORM WILL BE HELD FOR 12 MONTHS FROM DATE OF SIGNING
(For minors aged 8-15 consent form to be signed by parent or guardian)

Sensory Evaluation of Camembert Cheese

- I have read and understood the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

- I agree to voluntarily participate in this study under the conditions set out in the Information Sheet.

- I understand I have the right to withdraw from the study at any time and to decline to answer any particular questions.

- I have advised and discussed with the Researcher any potentially relevant cultural, religious or ethical beliefs that may prevent me from consuming the Foods under consideration.

Participants Signature: ______________________________ **Date:** ____________

Full Name - printed ____

Consumer Trial- incomplete block design

Six samples, four were presented to each subject.

Table A4: Summary of the description of each Camembert Cheese sample

Sample	Description
1	+4'C Control
2	Reference
3	-2'C Control
4	Treatment: -2'C (TWO weeks)
5	Treatment: -2'C (FOUR weeks)
6	Treatment: -2'C (SIX weeks)

Table A5: Incomplete block design of the Camembert cheese samples that were presented to each consumer

Consumer	Sample 1	Sample 2	Sample 3	Sample 4
1, 16, 31, 46,	1	2	3	4
2, 17, 32, 47,	6	4	5	1
3, 18, 33, 48	3	5	6	2
4, 19, 34, 49	2	3	1	5
5, 20, 35, 50	4	1	2	6
6, 21, 36, 51	5	6	4	3
7, 22, 37, 52	1	2	3	6
8, 23, 38, 53	3	4	5	1
9, 24, 39, 54	2	5	6	4
10, 25, 40, 55	4	1	2	5
11, 26, 41, 56	5	6	1	3
12, 27, 42, 57	6	3	4	2
13, 28, 43, 58	1	2	5	6
14, 29, 44, 59	3	4	6	1
15, 30, 45, 60	2	3	4	5

Consumer testing evaluation form

You have FOUR samples to evaluate. Please taste each sample in the order which is indicated, and rate each attribute by indicating your acceptability on the scale.

Please try some cracker and water between the samples to cleanse your palate.

Are you:

Male	☐
Female	☐

Which age bracket do you fall into?

18 – 24	☐
25 – 29	☐
30 – 34	☐
35 – 39	☐
40 – 44	☐
45 – 49	☐
50 +	☐

How often would you consume camembert cheese?

More than once per week	☐
Once per fortnight	☐
Once per month	☐
Once per year	☐

SAMPLE: ______________

1. What do you think of the APPEARANCE of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much — Like very much

2. What do you think of the AROMA of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much — Like very much

3. What do you think of the *intensity* of the AROMA of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Too weak for me — Just right — Too strong for me

4. What do you think of the FLAVOUR of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much — Like very much

5. What do you think of the *intensity* of the FLAVOUR of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Too weak for me — Just right — Too strong for me

6. What do you think of the bitter FLAVOUR of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much — Like very much

7. What do you think of the *intensity* of the bitter FLAVOUR of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Too weak for me — Just right — Too strong for me

8. What do you think of the TEXTURE of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much — Like very much

9. What do you think of the creamy TEXTURE of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much — Like very much

10. What do you think of the *intensity* of the creamy TEXTURE of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Not creamy enough — Just right — Too creamy

11. What do you think of the sample overall?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much — Like very much

Do you have a reason for your choice? Please describe:

____

____

12. How likely would you be to purchase this sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Not at all likely — Maybe buy — Very likely

Do you have a reason for your choice? Please describe:

____

____

SAMPLE: ____________

1. What do you think of the APPEARANCE of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much Like very much

2. What do you think of the AROMA of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much Like very much

3. What do you think of the *intensity* of the AROMA of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Too weak for me Just right Too strong for me

4. What do you think of the FLAVOUR of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much Like very much

5. What do you think of the *intensity* of the FLAVOUR of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Too weak for me Just right Too strong for me

6. What do you think of the bitter FLAVOUR of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much Like very much

7. What do you think of the *intensity* of the bitter FLAVOUR of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Too weak for me Just right Too strong for me

8. What do you think of the TEXTURE of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much Like very much

9. What do you think of the creamy TEXTURE of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much Like very much

10. What do you think of the *intensity* of the creamy TEXTURE of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Not creamy enough Just right Too creamy

11. What do you think of the sample overall?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much Like very much

Do you have a reason for your choice? Please describe:

____

____

12. How likely would you be to purchase this sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Not at all likely Maybe buy Very likely

Do you have a reason for your choice? Please describe:

____

____

SAMPLE: ______________

1. What do you think of the APPEARANCE of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much | Like very much

2. What do you think of the AROMA of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much | Like very much

3. What do you think of the *intensity* of the AROMA of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Too weak for me | Just right | Too strong for me

4. What do you think of the FLAVOUR of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much | Like very much

5. What do you think of the *intensity* of the FLAVOUR of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Too weak for me | Just right | Too strong for me

6. What do you think of the bitter FLAVOUR of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much | Like very much

7. What do you think of the *intensity* of the bitter FLAVOUR of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Too weak for me | Just right | Too strong for me

8. What do you think of the TEXTURE of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much | Like very much

9. What do you think of the creamy TEXTURE of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much | Like very much

10. What do you think of the *intensity* of the creamy TEXTURE of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Not creamy enough | Just right | Too creamy

11. What do you think of the sample overall?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much | Like very much

Do you have a reason for your choice? Please describe:

____

____

12. How likely would you be to purchase this sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Not at all likely | Maybe buy | Very likely

Do you have a reason for your choice? Please describe:

____

____

SAMPLE: ____________

1. What do you think of the APPEARANCE of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much — Like very much

2. What do you think of the AROMA of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much — Like very much

3. What do you think of the_*intensity* of the AROMA of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Too weak for me — Just right — Too strong for me

4. What do you think of the FLAVOUR of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much — Like very much

5. What do you think of the *intensity* of the FLAVOUR of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Too weak for me — Just right — Too strong for me

6. What do you think of the bitter FLAVOUR of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much — Like very much

7. What do you think of the *intensity* of the bitter FLAVOUR of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Too weak for me — Just right — Too strong for me

8. What do you think of the TEXTURE of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much — Like very much

9. What do you think of the creamy TEXTURE of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much — Like very much

10. What do you think of the *intensity* of the creamy TEXTURE of the sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Not creamy enough — Just right — Too creamy

11. What do you think of the sample overall?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike very much — Like very much

Do you have a reason for your choice? Please describe:

____

____

12. How likely would you be to purchase this sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Not at all likely — Maybe buy — Very likely

Do you have a reason for your choice? Please describe:

____

____

Of the four samples which you have tried today, which sample did you prefer?

____

Do you have a reason for your choice? Please describe:

____

Demographic Information

Table A6: Gender

Gender	Number of Responses	Percentage (%)
Male	29	59.2
Female	20	40.8
Non-response	0	0
	49	100

Table A7: Age

Age	Number of Responses	Percentage (%)
18 – 24	17	34.7
25 – 29	8	16.3
30 – 34	3	6.1
35 – 39	6	12.2
40 – 44	0	0
45 – 49	5	10.2
50+	9	18.4
Non-response	1	2.0
	49	100

Table A8: Frequency of Consumption

Frequency of Consumption	Number of responses	Percentage (%)
More than once per week	10	20.4
Once per fortnight	19	38.8
Once per month	20	40.8
Once per year	0	0
Non-response	0	0
	49	100

Descriptive Statistics

[Variables: Appearance, Aroma, Intensity of Aroma, Flavour, Intensity of Flavour, Bitter Flavour, Intensity of Bitter Flavour, Texture, Creamy Texture, Intensity of Creamy Texture, Overall Liking, Likelihood of Purchase **BY** Sample]

Table A9: Appearance

Sample	N not Missing	N Missing	Mean	Median	SE Mean	Std Deviation
+4°C Control	33	0	6.636	7.000	0.317	2.133
Reference	33	0	7.515	8.000	0.392	2.252
-2°C Control	33	0	8.364	8.000	0.328	1.884
Treatment; -2°C (TWO weeks)	33	0	8.000	8.000	0.351	1.984
Treatment; -2°C (FOUR weeks)	33	0	6.879	7.000	0.331	1.900
Treatment; -2°C (SIX weeks)	32	0	7.594	8.000	0.375	2.123

Table A10: Aroma

Sample	N not Missing	N Missing	Mean	Median	SE Mean	Std Deviation
+4°C Control	33	0	6.727	6.000	0.321	1.842
Reference	32	1	6.281	6.000	0.454	2.568
-2°C Control	33	0	7.152	7.000	0.329	1.889
Treatment; -2°C (TWO weeks)	32	0	6.219	6.000	0.326	1.845
Treatment; -2°C (FOUR weeks)	33	0	6.061	6.000	0.361	2.076
Treatment; -2°C (SIX weeks)	32	0	6.938	7.000	0.370	2.094

Table A11: *Intensity* of Aroma

Sample	N not Missing	N Missing	Mean	Median	SE Mean	Std Deviation
+4°C Control	33	0	5.242	5.000	0.392	2.250
Reference	33	0	5.212	6.000	0.424	2.434
-2°C Control	33	0	5.000	5.000	0.326	1.871
Treatment; -2°C (TWO weeks)	32	0	4.656	5.000	0.383	2.164
Treatment; -2°C (FOUR weeks)	33	0	5.515	6.000	0.411	2.360
Treatment; -2°C (SIX weeks)	32	0	5.500	6.000	0.345	1.951

Table A12: Flavour

Sample	N not Missing	N Missing	Mean	Median	SE Mean	Std Deviation
+4°C Control	33	0	7.182	8.000	0.381	2.186
Reference	33	0	5.879	5.000	0.524	3.008
-2°C Control	33	0	7.545	8.000	0.329	1.889
Treatment; -2°C (TWO weeks)	32	0	7.469	8.000	0.324	1.831
Treatment; -2°C (FOUR weeks)	33	0	6.606	8.000	0.422	2.423
Treatment; -2°C (SIX weeks)	32	0	7.781	8.000	0.344	1.947

Highlighted cells indicate where the mean score is on the "dislike very much" side of the scale

Table A13: *Intensity* of Flavour

Sample	N not Missing	N Missing	Mean	Median	SE Mean	Std Deviation
+4°C Control	33	0	6.091	6.000	0.378	2.170
Reference	33	0	6.182	6.000	0.355	2.038
-2°C Control	32	1	5.594	6.000	0.323	1.829
Treatment; -2°C (TWO weeks)	32	0	5.375	6.000	0.209	1.185
Treatment; -2°C (FOUR weeks)	33	0	7.000	7.000	0.279	1.601
Treatment; -2°C (SIX weeks)	32	0	6.094	6.000	0.267	1.510

Table A14: Bitter Flavour

Sample	N not Missing	N Missing	Mean	Median	SE Mean	Std Deviation
+4°C Control	33	0	6.121	6.000	0.408	2.342
Reference	33	0	6.242	6.000	0.426	2.45
-2°C Control	32	1	7.813	8.000	0.296	1.674
Treatment; -2°C (TWO weeks)	32	0	6.781	7.000	0.326	1.845
Treatment; -2°C (FOUR weeks)	33	0	5.515	5.000	0.481	2.763
Treatment; -2°C (SIX weeks)	32	0	6.906	7.000	0.374	2.115

Highlighted cells indicate where the mean score is on the "dislike very much" side of the scale

Table A15: *Intensity* of Bitter Flavour

Sample	N not Missing	N Missing	Mean	Median	SE Mean	Std Deviation
+4°C Control	33	0	6.333	6.000	0.398	2.287
Reference	33	0	5.333	6.000	0.405	2.327
-2°C Control	32	1	5.656	6.000	0.344	1.945
Treatment; -2°C (TWO weeks)	32	0	5.625	6.000	0.283	1.601
Treatment; -2°C (FOUR weeks)	33	0	7.455	8.000	0.337	1.938
Treatment; -2°C (SIX weeks)	32	0	6.156	6.000	0.281	1.588

Table A16: Texture

Sample	N not Missing	N Missing	Mean	Median	SE Mean	Std Deviation
+4°C Control	31	2	6.871	7.000	0.384	2.141
Reference	33	0	7.212	8.000	0.488	2.804
-2°C Control	32	1	7.844	8.500	0.362	2.050
Treatment; -2°C (TWO weeks)	31	1	7.806	8.000	0.336	1.869
Treatment; -2°C (FOUR weeks)	33	0	7.485	8.000	0.364	2.093
Treatment; -2°C (SIX weeks)	31	1	7.903	9.000	0.363	2.022

Table A17: Creamy Texture

Sample	N not Missing	N Missing	Mean	Median	SE Mean	Std Deviation
+4°C Control	33	0	6.909	8.000	0.416	2.390
Reference	33	0	7.333	8.000	0.476	2.735
-2°C Control	32	1	7.313	8.000	0.380	2.147
Treatment; -2°C (TWO weeks)	32	0	7.531	7.000	0.356	2.016
Treatment; -2°C (FOUR weeks)	32	1	7.813	8.000	0.363	2.055
Treatment; -2°C (SIX weeks)	32	0	7.531	8.000	0.354	2.000

Table A18: *Intensity* of Creamy Texture

Sample	N not Missing	N Missing	Mean	Median	SE Mean	Std Deviation
+4°C Control	33	0	5.182	5.000	0.287	1.648
Reference	32	1	5.938	6.000	0.416	2.355
-2°C Control	32	1	5.625	6.000	0.307	1.737
Treatment; -2°C (TWO weeks)	31	1	5.806	6.000	0.291	1.621
Treatment; -2°C (FOUR weeks)	32	1	6.438	6.000	0.291	1.645
Treatment; -2°C (SIX weeks)	32	0	5.937	6.000	0.304	1.722

Table A19: Overall Liking

Sample	N not Missing	N Missing	Mean	Median	SE Mean	Std Deviation
+4°C Control	33	0	6.667	7.000	0.400	2.300
Reference	33	0	6.485	7.000	0.461	2.647
-2°C Control	33	0	7.758	8.000	0.311	1.786
Treatment; -2°C (TWO weeks)	32	0	7.781	8.000	0.304	1.718
Treatment; -2°C (FOUR weeks)	33	0	6.606	7.000	0.481	2.761
Treatment; -2°C (SIX weeks)	32	0	8.063	8.000	0.320	1.813

Table A20: Likelihood of Purchase

Sample	N not Missing	N Missing	Mean	Median	SE Mean	Std Deviation
+4^{o}C Control	33	0	6.152	6.000	0.485	2.785
Reference	33	0	5.424	6.000	0.561	3.221
-2^{o}C Control	33	0	7.273	7.000	0.354	2.035
Treatment; -2^{o}C (TWO weeks)	32	0	7.375	8.000	0.364	2.060
Treatment; -2^{o}C (FOUR weeks)	33	0	5.606	6.000	0.488	2.806
Treatment; -2^{o}C (SIX weeks)	30	2	7.533	7.000	0.361	1.978

Highlighted cells indicate where the mean score is on the "dislike very much" side of the scale

General Linear Model

[Variables: Appearance, Aroma, Intensity of Aroma, Flavour, Intensity of Flavour, Bitter Flavour, Intensity of Bitter Flavour, Texture, Creamy Texture, Intensity of Creamy Texture, Overall Liking **BY** Judge and Sample]

Table A21: Table of Significant Effects

Attribute	Judge	Sample
Appearance	0.101	0.003
Aroma	0.000	0.360
Intensity of Aroma	0.001	0.383
Flavour	0.805	0.035
Intensity of Flavour	0.010	0.013
Bitter Flavour	0.139	0.058
Intensity of Bitter Flavour	0.199	0.003
Texture	0.116	0.171
Creamy Texture	0.040	0.762
Intensity of Creamy Texture	0.000	0.149
Overall Liking	0.441	0.051

Highlighted figures indicate significant effects

One-way ANOVA

[Only carried out on attributes that were found to be significantly different at 99% CI; in terms of sample]

Appearance versus Sample

Source	DF	SS	MS	F	P
Sample	5	70.25	14.05	3.34	0.006
Error	190	798.75	4.20		
Total	195	868.99			

S = 2.050   R-Sq = 8.08%   R-Sq(adj) = 5.66%

```
                         Individual 99% CIs For Mean Based on
                         Pooled StDev
Level   N   Mean  StDev  ------+---------+---------+---------+---
1      33  6.636  2.133  (--------*--------)b
2      33  7.515  2.252            (--------*--------)ab
3      33  8.364  1.884                       (--------*-------)a
4      32  8.000  1.984                  (--------*--------)ab
5      33  6.879  1.900     (--------*--------)b
6      32  7.594  2.123             (--------*--------)ab
                         ------+---------+---------+---------+---
                             6.40      7.20      8.00      8.80
```

One-way ANOVA: Intensity of Flavour versus Sample

Source	DF	SS	MS	F	P
Sample	5	51.69	10.34	3.35	0.006
Error	189	583.57	3.09		
Total	194	635.26			

S = 1.757   R-Sq = 8.14%   R-Sq(adj) = 5.71%

```
                         Individual 99% CIs For Mean Based on Pooled StDev
Level   N   Mean  StDev     +---------+---------+---------+---------
1      33  6.091  2.170            (------*-------)ab
2      33  6.182  2.038             (------*-------)ab
3      32  5.594  1.829      (-------*-------)b
4      32  5.375  1.185    (------*-------)b
5      33  7.000  1.601                     (-------*------)a
6      32  6.094  1.510            (------*-------)ab
                           +---------+---------+---------+---------
                         4.80      5.60      6.40      7.20
```

One-way ANOVA: Intensity of Bitter Flavour versus Sample

Source	DF	SS	MS	F	P
Sample	5	95.36	19.07	4.90	0.000
Error	189	735.79	3.89		
Total	194	831.15			

S = 1.973   R-Sq = 11.47%   R-Sq(adj) = 9.13%

```
                              Individual 99% CIs For Mean Based on
                              Pooled StDev
Level   N   Mean  StDev  ---+---------+---------+---------+------
1      33  6.333  2.287            (-----*------)ab
2      33  5.333  2.327  (-----*------)b
3      32  5.656  1.945     (------*-----)b
4      32  5.625  1.601    (------*------)b
5      33  7.455  1.938                      (------*-----)a
6      32  6.156  1.588          (------*-----)b
                              ---+---------+---------+---------+------
                               5.0      6.0      7.0      8.0
```

Correlations

[Appearance, Aroma, Flavour, Bitter Flavour, Texture, Creamy Texture and Overall acceptability]

Table A22: Correlations of what attribute most drives consumer's acceptability scores

	Appearance	Aroma	Flavour	Bitter Flavour	Texture	Creamy Texture
Overall Acceptability	0.540	0.423	0.775	0.617	0.497	0.477
	0.000	0.000	0.000	0.000	0.000	0.000

Pearson Correlation
P-value

This output shows that Flavour is the primary attribute that drives consumer acceptability

Table A23: Correlation between flavour attributes

	Flavour
Bitter Flavour	0.551
	0.000

Pearson Correlation
P-value

Table A24: Correlation between Texture attributes

	Texture
Creamy Texture	0.719
	0.000

Pearson Correlation
P-value

Regression Analysis

[Model: Overall Acceptability against Appearance, Aroma, Flavour, Bitter Flavour, Texture, Creamy Texture]

Overall Liking = - 0.635 + 0.176 Appearance + 0.0146 Aroma + 0.492 Flavour + 0.215 Bitter Flavour + 0.108 Texture + 0.103 Creamy Texture

R-Sq = 72.3% R-Sq (adj) = 71.4%

Overall Liking = 1.83 + 0.763 Flavour

R-Sq = 60.1% R-Sq (adj) = 59.9%

Overall Liking = - 0.105 + 0.539 Flavour + 0.230 Bitter Flavour + 0.267 Appearance

R-Sq = 70.2% R-Sq (adj) = 69.7%

Consumer responses

Sample	Consumer Comments
-2°C storage (ZERO weeks)	Tasty Not bitter Tastes good Bitter flavour in rind Bitter after-taste Bitter rind is off-putting Too bitter (**) Cheese not very soft Not soft enough Still needs to ripen Salty Would prefer a stronger after-taste Too young, would improve with age Not very creamy Off-flavour Rubbery texture Don't like the after-taste Lacks a lot of intensity Prefer stronger cheese Not so keen on the flavour Aroma too weak Not enough flavour Not creamy enough (**) Too white-didn't like how it looked Appearance-looked slightly brown near the rind so not appealing Bitter aftertaste comes through after eating Best combination of flavour and texture Not enough flavour Too weak flavour Grey/ yellow colour puts me off Strange colour-almost grey next to the crust Creamy, soft Good flavour Most resembles a "typical" camembert

Sample	Consumer Comments
-2^{o}C storage (TWO weeks)	Not very bitter No bitterness Not too bitter (*) Nice flavour (**) A little bitter and/ or salty Not creamy enough Slightly stronger flavour than -2^{o}C control Nice taste and after-tatste Good texture and flavour Ready for eating Very bitter smells-smells not right Firm Looks okay Has the right texture Taste is only so-so Not strong flavour Too bland and firm Most camemberty of them all (in appearance and taste) Sweeter than -2^{o}C storage (ZERO weeks) and -2^{o}C storage (SIX weeks) Mild Too mild Not much taste Nice creamy Clean and nice Not soft enough Texture very good Needs to be stronger in flavour/ bitterness

Sample	Consumer Comments
-2°C storage (FOUR weeks)	A little over-ripe Too old (*) Too much ammonia aroma and flavour Very salty Ammonia taste puts me off Like the overall taste Crust a bit thick Bitter aroma Good texture Bitter taste is too strong Too bitter (****) Very bitter Too bitter aftertaste Tad bitter Bitter after-taste is unpleasant A little too bitter, but still pleasant Stronger smell than -2°C Control Best overall Nice Full aroma Very tasty Too creamy Don't like the taste Taste did not appeal Too strong flavour-overrides everything else Looks a bit grey Greasy rather than creamy Rind too crunchy

Sample	Consumer Comments
-2^{o}C storage (SIX weeks)	Perfect Lovely Excellent As good as any camembert I have ever tasted Nice all round Like its taste Not as bitter after-taste (compared to -2^{o}C storage (ZERO weeks)) Less bitter than (-2^{o}C storage (ZERO weeks)) Very good bitter after-taste/ finish Too bitter Would prefer if less bitter Good blend if in mood for bitter cheese Bitter aroma A bit bitter (*) Like this type of cheese Like the texture particularly Good but too firm Not enough flavour (*) Not too bitter but softest texture Not too bitter or creamy Good flavour (*) Good texture Appearance-looked slightly brown near the rind so not appealing Right mix of creamy and flavour… Tastes good, very creamy Good balance of taste, creaminess Nice consistency Too white crust Texture okay, needs to ripen Clean flavour Good flavour Good cheese Similar to -2^{o}C Control Very good finish Creamy and strong texture

Sample	Consumer Comments
-2^{o}C control	Texture good Flavour good Good taste (*) Good flavour and apperanace Little too hard No bitterness Not too bitter (**) Not very bitter Not bitter Not a lot of flavour (too weak) Crust too white Just right for consumption today Very easy to eat Just right Bland taste (*) Slightly dusty/ musty Too salty Good all-round cheese Perfect blend of taste and texture Delicious all-round cheese Nice taste (*) Nice consistency Nice appearance Very nice taste Very nice looks Pleasant Smells bitter Too firm (*) Tastes a bit goat-milk flavoured-I don't like goat milk flavoured cheese Would appeal to a wide group Very tasty Nice I wouldn't call this camembert Creamy Flavour not as strong as I would like Would prefer a richer/ stronger cheese

Sample	Consumer Comments
Reference	Nice texture
	Good texture
	Tastes good
	Needs to be more bitter
	Not too bitter
	Not bitter
	Not bitter at all
	Quite bitter
	No bitter aftertaste
	More bitter than -2°C storage (ZERO weeks)
	Not as creamy
	Aroma and flavour like old sweaty socks
	Flavour too weak
	Flavour horrible
	Good creamy flavour
	Buttery notes
	Creamy texture
	Creamy taste is nice
	Texture is not creamy enough
	Like the taste
	Not strong enough
	Better taste and texture
	Like the texture particularly
	Not too much mould, so can see the colour of the cheese
	Quite soft
	Not too firm
	Good cheese but not strong enough
	Tart, acidic, like cheddar
	Sour
	Didn't taste or look like camembert (except for the rind_
	Texture too crumbly
	Liked it as a cheese, but not camembert enough for me
	More taste + tangy
	Better smell
	Yuck
	Bland flavour
	Very creamy texture
	No flavour
	Not very attractive
	Texture sponge
	Texture too dry

	Dry Appearance looks a bit dry Odour not over-powering Nice consistency Tastes too much like dairy/milk Quite good Like French camembert Too young Not ready for consumption No off-flavours Nice and creamy Does not represent a “real” camembert Too sour Appealing in appearance and taste

Quantitative Descriptive Analysis (QDA) research

Consent and confidentiality agreement

Massey University
Te Kunenga ki Pürehuroa

QDA research monitoring the sensory changes in Camembert cheese

Researchers Name:	Shannon Swan	Supervisors Name:	Dr. Marie Wong
Contact Details:	Shannon.L.Swan@gmail.com	Contact Details:	m.wong@massey.ac.nz

You are invited to take part in a trained panel sensory evaluation exercise to monitor the sensory changes in camembert cheese over time.

Your participation in this activity will take approximately two to three hours per week while training, and up to one hour per week while testing.

The foods you will be tasting contain the following components that can be harmful or cause allergic reactions with certain groups of people (delete those not contained in the foods in question). You are requested not to partake if you may be adversely affected by **Milk** and **milk derivatives** and the product may also contain traces of **nuts**, **sesame seeds**, or **peanuts** and derivatives

The information collected in this study will be used to complete an assignment in partial fulfilment of the Masters of Technology in Food Technology. No data linked to an individual's identity will be collected.

If you have any questions about this work, please contact one of the people indicated above.

This project has been reviewed and approved by the Massey University Human Ethics Committee, PN Protocol HEC: PN Protocol 03/34*).* If you have any concerns about the conduct of this research, please contact Professor Sylvia V Rumball, Chair, Massey University Campus Human Ethics Committee: Palmerston North, telephone 06 350 5249, email S.V.Rumball@massey.ac.nz.

QDA research monitoring the sensory changes in Camembert cheese

CONSENT FORM

THIS CONSENT FORM WILL BE HELD FOR 12 MONTHS FROM DATE OF SIGNING

- I have read and understood the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

- I agree to voluntarily participate in this study under the conditions set out in the Information Sheet.

- I understand I have the right to withdraw from the study at any time and to decline to answer any particular questions.

- I have advised and discussed with the Researcher any potentially relevant cultural, religious or ethical beliefs that may prevent me from consuming the Foods under consideration.

Participants Signature: .... **Date:** ....

Full Name - printed ....

QDA research monitoring the sensory changes in Camembert cheese

CONFIDENTIALTY AGREEMENT

As a participant of this study you may be exposed to some information that is commercially sensitive and confidential, therefore it is asked that you agree to keep all information concerning this project confidential.

I .... (Full Name - printed) agree to keep confidential all information concerning the project "**QDA research monitoring the sensory changes in camembert cheese".**

Signature: .... Date: ....

Full Name - printed ....

Aroma acuity screening

Panellists were presented with four three-digit blind-coded samples of each odour (see **Table A25**) and were asked to rank each sample from "Low Intensity" to "High Intensity". Samples were prepared by diluting the odour sample in distilled water to the required concentration.

Table A25: Concentration of each odour, diluted in distilled water, presented to panellists to test for odour acuity

Odour	**Concentration** (w/v)		
	Low	Medium	High
Butyric acid	0.001	0.01	0.1
Isoamyl acetate	0.001	0.01	0.1

According to Meilgaard *et al.,* (2007) candidates were accepted if they were able to correctly rank samples, or who inverted the adjacent pair of samples.

Product	**Supplier**
Butyric acid	Sensient Technologies (Auckland, New Zealand)
Isoamyl acetate	Sensient Technologies (Auckland, New Zealand)

Flavour acuity screening

Panellists were presented with four three-digit blind-coded samples of each taste sensation (see **Table A26**). Samples were prepared by diluting the taste sample in distilled water to the required concentration. The panellists were asked to:

1. Identify the taste sensation
2. Rank each sample from "Low Intensity" to "High Intensity"

Table A26: Concentration of each taste sensation presented to panellists to test for taste acuity

Taste	Concentration (w/v)			
	Low	Medium		High
Sweet/(sucrose)	1.00	2.00	5.00	10.00
Sour/(citric acid)	0.025	0.05	0.10	0.15
Bitter/(caffeine)	0.03	0.06	0.13	0.26
Salty/(sodium chloride)	0.10	0.20	0.50	1.00

Table 27: Protein determination product/ supplier list

Product	Supplier
Sucrose	Chelsea sugar (Auckland, New Zealand)
Citric acid	Hansells citric acid (Auckland, New Zealand)
Caffiene	Scharlau Caffiene (Auckland, New Zealand)
Sodium chloride	Cerebos Greggs table salt (Auckland New Zealand)

QDA Product testing questionnaire

PRODUCT TESTING [week number]

NAME: ___________________________

SAMPLE NUMBER: _________________

How intense is the **whiteness of the mould** across the surface of the cheese?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

NOT white — Moderate — VERY white

How **dry** is the crust of the cheese, in comparison to the centre?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

NOT dry — Moderate — VERY dry

Please evaluate this by smelling the mould

How intense is the **mushroom aroma**?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

NO mushroom aroma — Moderate — VERY mushroom aroma

How intense is the **dirty/ stale/ cardboard aroma**?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

NO dirty/ stale/ cardboard aroma — Moderate — VERY dirty/ stale/ cardboard aroma

How intense is the **ammonia aroma**?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

NO ammonia aroma — Moderate — VERY ammonia aroma

Please evaluate the following three attributes by compressing a cross section of the sample between your thumb and index finger

How **springy** is the cheese?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

NOT springy — Moderate — VERY springy

How intense is the **firmness** of the cheese?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

NOT firm — Moderate — VERY firm

Please evaluate the *rind crunch* from the first bite into a cross-section of the cheese.

How intense is the **Rind Crunch** on the first bite through the cheese?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

NO rind crunch — Moderate — INTENSE rind crunch

Please evaluate the following attributes by masticating the sample and spreading it evenly over your tongue

How intense is the **Bitter** flavour?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

WEAK bitter flavour — Moderate — STRONG bitter flavour

How **Acidic/ sour** is the cheese?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Weak acidity/ sourness flavour — Moderate — STRONG acidity/ sourness flavour

Please evaluate the next attributes from just the curd of the cheese by masticating the sample and distributing it evenly throughout your mouth

How would you rate the intensity of the **stickiness** of the curd?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

NOT sticky — Moderate — VERY sticky

How would your rate the intensity of the **creamy mouthfeel** of the cheese?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

NOT creamy — Moderate — VERY creamy

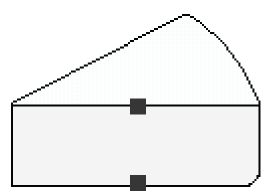
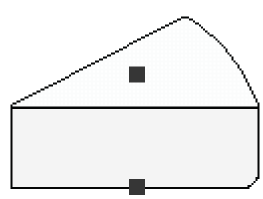
How would you rate the intensity of the **smoothness** (particulate size following mastication) of the cheese?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

NOT smooth — Moderate — VERY Smooth

☺ **THANKS** ☺

DEFINITIONS

Term	Definition
Whiteness of the mould	Degree of colour change (NOT white -> VERY White)
Dryness of the crust	The "crustiness" of the cheese immediately under the rind; in comparison the centre of the cheese
Mushroom aroma	The intensity of the fresh field mushroom aroma in the mould of the cheese (reference: fresh field mushrooms)
Dirty/ stale/ cardboard aroma	The intensity of the dusty/ stale/ cardboard aroma in the mould of the cheese (reference: wet cardboard)
Ammonia aroma	The intensity of the ammonia aroma in the mould of the cheese (reference: 0.25% ammonia dissolved in distilled water)
Springiness; tactile texture	The degree to which the cheese returns to its original height following a 25% compression. The compression is to be carried out using the thumb and index finger, on the cross-sectional edge of the cheese, half way along the length of the sample: 
Firmness; tactile texture	The force required to compress the cheese between the thumb and index finger/ resistance of the cheese to deformation when compressed between the thumb and index finger: 
Rind Crunch	The difference in texture between the rind of the cheese and the curd from the first bite into a cross-section of the cheese
Fresh buttery flavour	The intensity of the fresh buttery/ diacetyl flavour (reference: fresh mainland butter)
Acidic/ sour flavour	The intensity of the acidity/ sourness in the cheese (reference: 0.1% citric acid in distilled water)

Smoothness: mouthfeel	The degree to which the cheese fractures and grains form when of the cheese when mushed over the tongue following initial mastication (2-5 chews)
Stickiness; mouthfeel	The adhesiveness/ pastiness of the sample against the palate and around the teeth throughout mastication (reference: smooth peanut butter)
Creamy; mouthfeel	The creaminess of the curd over the tongue following mastication (reference: Mascapone)

Trained Panel; session summaries

QDA Session 1

Panellists: 9 Blind duplicate sample: +4°C Control

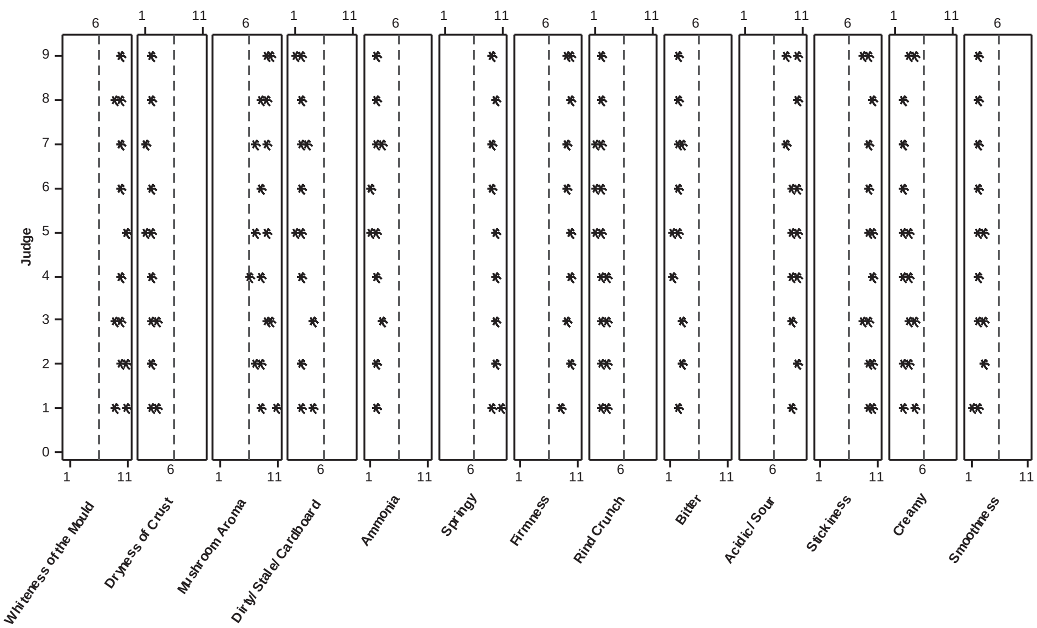


Figure A28: Panellist-orientated data for individual attributes and replications; session one

Table A28: Table of significant effects; session one

Attribute	Judge	Sample
Whiteness of the Mould	0.500	0.729
Dryness of the Crust	0.120	0.594
Mushroom Aroma	0.229	0.067
Dirty/ Stale/ Cardboard Aroma	0.053	0.282
Ammonia Aroma	0.018	1.000
Springiness	0.136	0.347
Firmness	0.000	0.347
Rind crunch	0.500	0.729
Bitter Flavour	0.003	0.169
Acidic/ Sour Flavour	0.217	0.729
Stickiness of the curd	0.159	0.681
Creamy mouthfeel	0.360	0.760
Smoothness	0.161	0.594

Highlighted cells indicate significant effects (p-value < 0.01)

Outcomes

- **Table A28** show's that the judges were not judging consistently for *firmness* or *bitter flavour* (p-values < 0.01). It is possible that there is a significant difference between the blind duplicate samples for these two attributes, however because of the inconsistency between the judges this can not be determined. Further training was required for the following product assessment (session 2) on each of these attributes.
- Judge 9 was an unusual observation for *Firmness*
- Judges 5 and 7 were unusual observations for *Bitter flavour*

QDA Session 2

Panellists: 8 Blind duplicate sample: +4°C Control

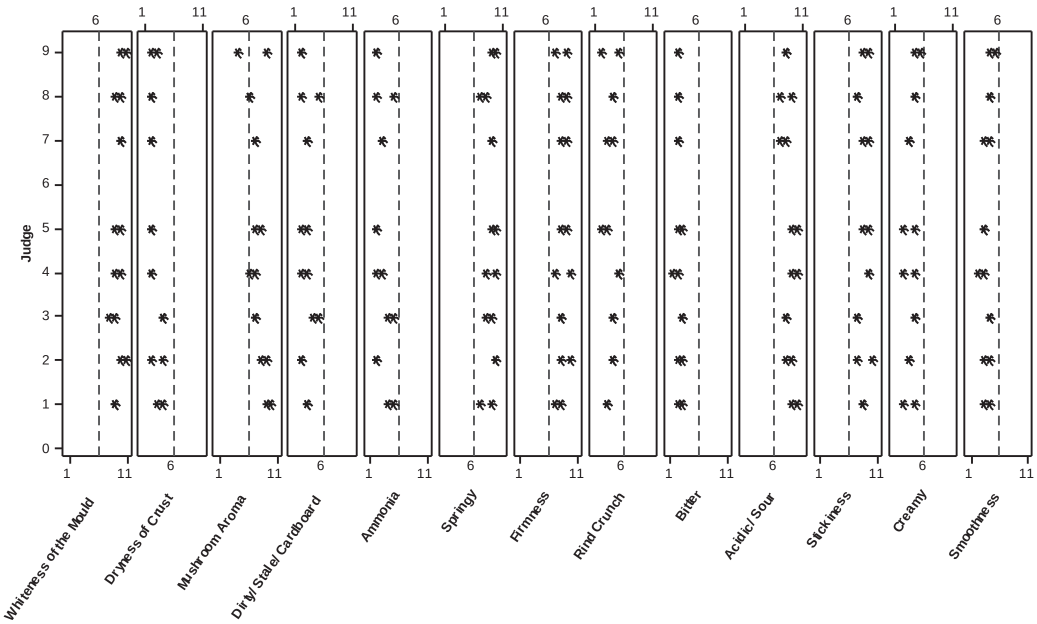


Figure A29: Panellist-orientated data for individual attributes and replications; session two

Table A29: Table of significant effects; session two

Attribute	Judge	Sample
Whiteness of the Mould	0.130	0.451
Dryness of the Crust	0.035	0.104
Mushroom Aroma	0.314	0.388
Dirty/ Stale/ Cardboard Aroma	0.251	0.598
Ammonia Aroma	0.109	1.000
Springiness	0.115	0.080
Firmness	0.782	0.038
Rindcrunch	0.188	0.140
Bitter Flavour	0.247	0.351
Acidic/ Sour Flavour	0.170	0.763
Stickiness of the curd	0.180	0.080
Creamy mouthfeel	0.280	0.041
Smoothness	0.017	0.011

Outcomes:

- The judges were scoring consistently for all attributes between the blind duplicate samples (indicated by the p-values being > 0.01)

QDA Session 3

Panellists: 8 Blind duplicate sample: -2°C Control

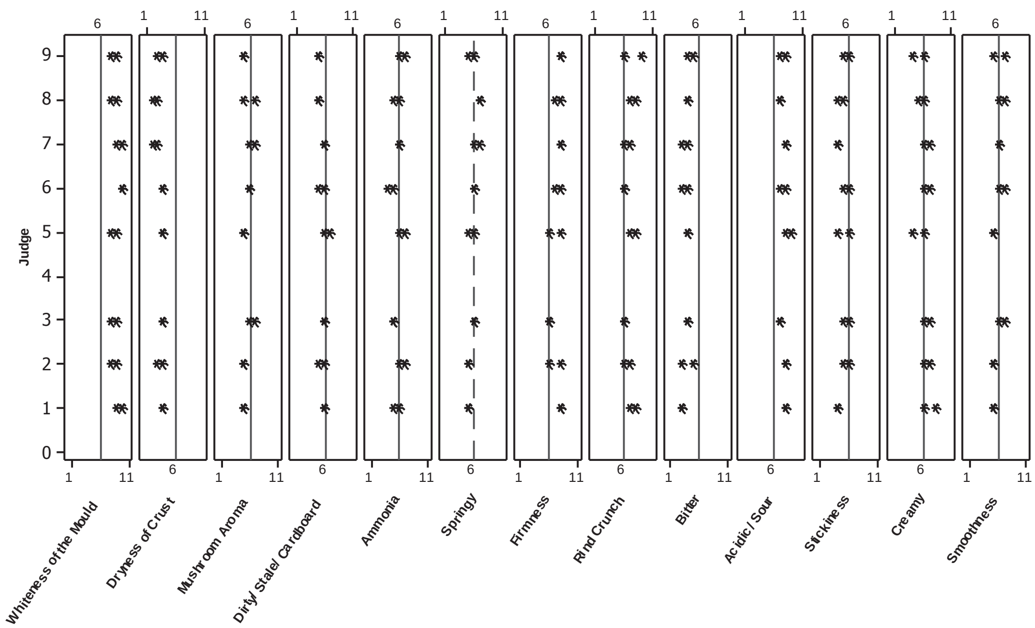


Figure A30: Panellist-orientated data for individual attributes and replications; session three

Table A30: Table of significant effects; session three

Attribute	Judge	Sample
Whiteness of the Mould	0.280	0.732
Dryness of the Crust	0.085	1.000
Mushroom Aroma	0.130	0.451
Dirty/ Stale/ Cardboard Aroma	0.104	0.598
Ammonia Aroma	0.109	1.000
Springiness	0.027	0.598
Firmness	0.253	0.227
Rindcrunch	0.519	1.000
Bitter Flavour	0.579	0.732
Acidic/ Sour Flavour	0.104	0.598
Stickiness of the curd	0.318	0.763
Creamy mouthfeel	0.500	0.826
Smoothness	0.187	0.732

Outcomes:

- The judges were scoring consistently for all attributes between the blind duplicate samples (indicated by the p-values being > 0.01)

QDA Session 4

Panellists: 9 Blind duplicate sample: -2^{o}C Control

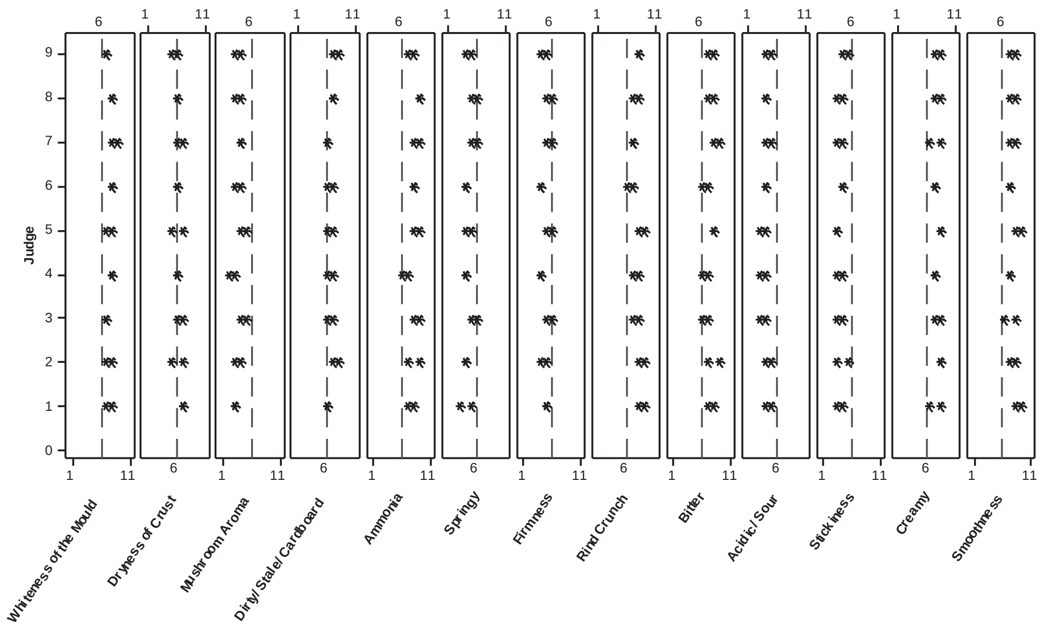


Figure A31: Panellist-orientated data for individual attributes and replications; session four

Table A31: Table of significant effects; session four

Attribute	Judge	Sample
Whiteness of the Mould	0.173	1.000
Dryness of the Crust	0.667	0.139
Mushroom Aroma	0.179	0.729
Dirty/ Stale/ Cardboard Aroma	0.122	0.104
Ammonia Aroma	0.212	1.000
Springiness	0.223	0.760
Firmness	0.060	0.104
Rindcrunch	0.124	0.729
Bitter Flavour	0.152	0.139
Acidic/ Sour Flavour	0.500	0.729
Stickiness of the curd	0.500	0.050
Creamy mouthfeel	0.820	0.782
Smoothness	0.350	0.225

Outcomes:

The judges were scoring consistently for all attributes between the blind duplicate samples (indicated by the p-values being > 0.01)

QDA Session 5

Panellists: 9 Blind duplicate sample: -2°C Control

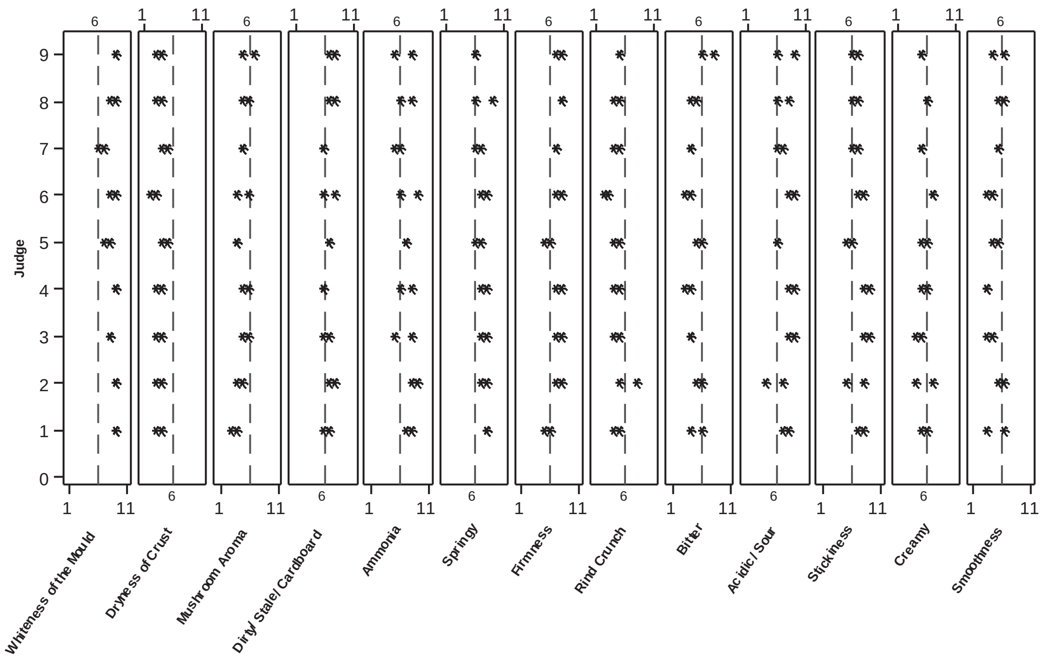


Figure A32: Panellist-orientated data for individual attributes and replications; session five

Table A32: Table of significant effects; session five

Attribute	Judge	Sample
Whiteness of the Mould	0.071	0.486
Dryness of the Crust	0.480	0.332
Mushroom Aroma	0.109	0.093
Dirty/ Stale/ Cardboard Aroma	0.301	0.512
Ammonia Aroma	0.561	0.585
Springiness	0.370	0.824
Firmness	0.121	0.614
Rindcrunch	0.158	0.428
Bitter Flavour	0.006	0.007
Acidic/ Sour Flavour	0.501	0.767
Stickiness of the curd	0.091	0.088
Creamy mouthfeel	0.460	0.216
Smoothness	0.254	0.626

Highlighted cells indicate significant effects (p-value < 0.01)

Outcomes:

- **Table A32** shows that there are significant sample effects in relation to the *bitter flavour* of the samples (p-value less than 0.01); therefore, any consistency between the judging of this attribute may be masked by this effect. Further training was required for the following product assessment (session 6) on each of these attributes.

QDA Session 6

Panellists: 9 Blind duplicate sample: Reference

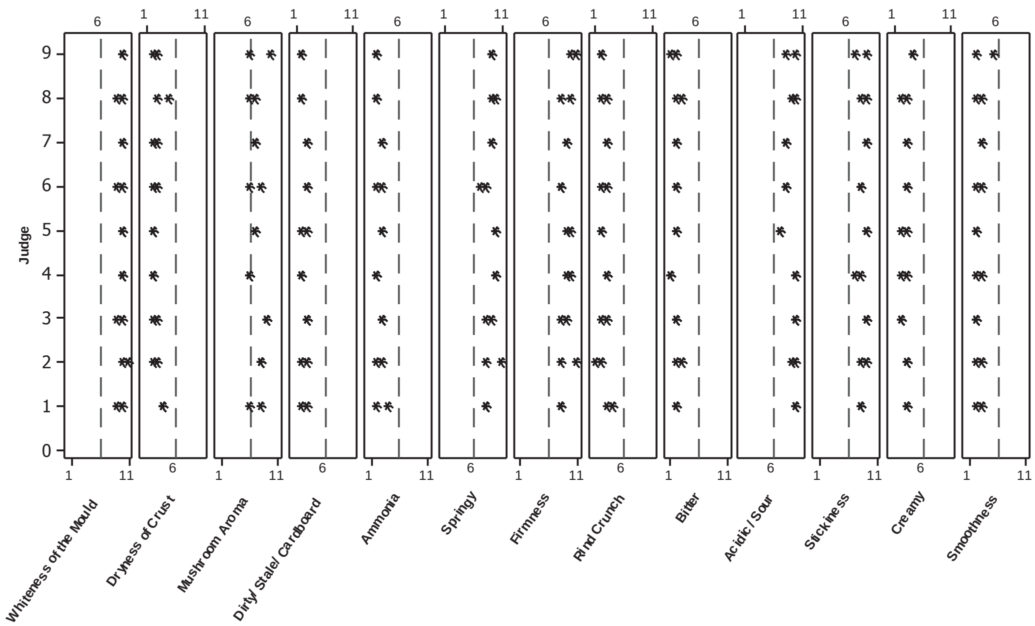


Figure A33: Panellist-orientated data for individual attributes and replications; session six

Table A33: Table of significant effects; session six

Attribute	Judge	Sample
Whiteness of the Mould	0.608	0.681
Dryness of the Crust	0.133	0.347
Mushroom Aroma	0.410	0.347
Dirty/ Stale/ Cardboard Aroma	0.071	0.081
Ammonia Aroma	0.348	0.447
Springiness	0.124	0.272
Firmness	0.358	0.500
Rindcrunch	0.113	0.381
Bitter Flavour	0.120	0.594
Acidic/ Sour Flavour	0.007	0.447
Stickiness of the curd	0.327	0.729
Creamy mouthfeel	0.018	0.081
Smoothness	0.500	0.021

Highlighted cells indicate significant effects (p-value < 0.01)

Outcomes:

- **Table A33** shows that there is a significant judge effect in relation to the *acidic/ sour* attribute (p-value < 0.01). There could be a significant difference between the blind duplicate samples for this attribute, however because of the inconsistency between the judges this can not be determined. Further training was required for the following product assessment (session 7) on each of these attributes.

QDA Session 7

Panellists: 9 Blind duplicate sample: Reference

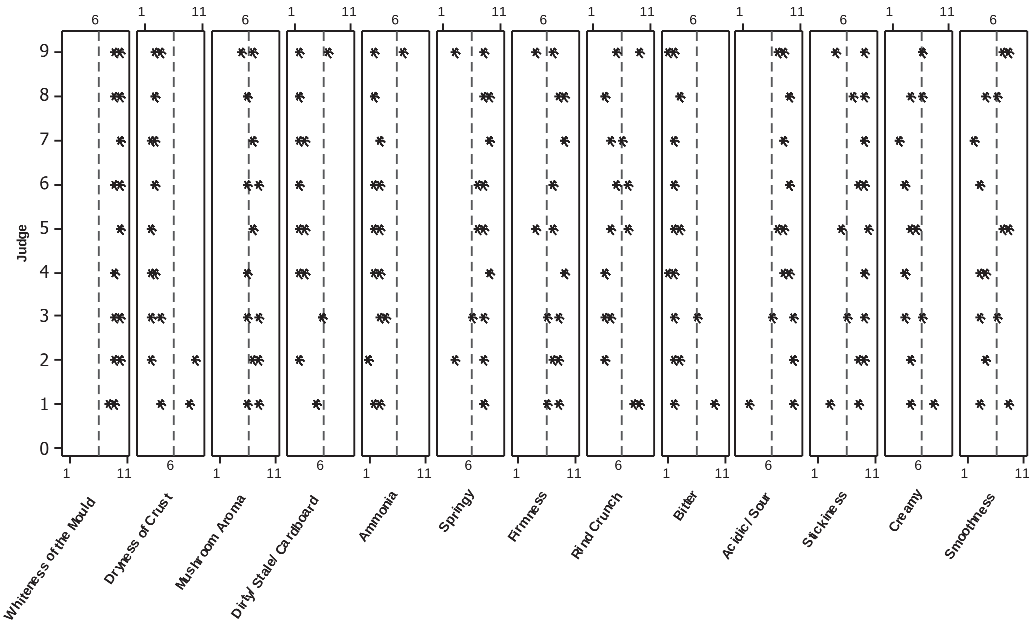


Figure A34: Panellist-orientated data for individual attributes and replications; session seven

Table A34: Table of significant effects; session seven

Attribute	Judge	Sample
Whiteness of the Mould	0.384	0.447
Dryness of the Crust	0.453	0.164
Mushroom Aroma	0.730	0.500
Dirty/ Stale/ Cardboard Aroma	0.091	0.729
Ammonia Aroma	0.467	0.498
Springiness	0.509	0.904
Firmness	0.126	0.282
Rindcrunch	0.027	0.259
Bitter Flavour	0.608	0.578
Acidic/ Sour Flavour	0.818	0.763
Stickiness of the curd	0.759	0.225
Creamy mouthfeel	0.128	0.299
Smoothness	0.071	0.468

Outcomes:

The judges were scoring consistently for all attributes between the blind duplicate samples (indicated by the p-values being > 0.01).

QDA Session 8

Panellists: 9 Blind duplicate sample: Reference

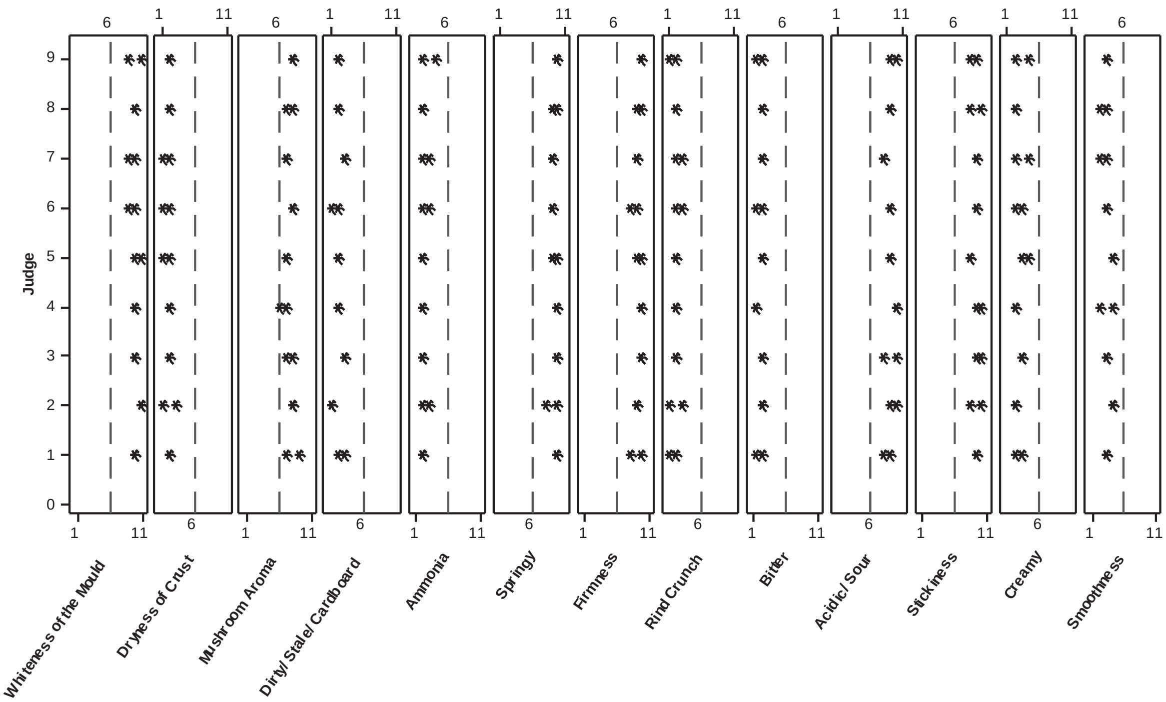


Figure A35: Panellist-orientated data for individual attributes and replications; session eight

Table A35: Table of significant effects; session eight

Attribute	Judge	Sample
Whiteness of the Mould	0.252	0.051
Dryness of the Crust	0.950	0.729
Mushroom Aroma	0.305	0.729
Dirty/ Stale/ Cardboard Aroma	0.003	0.169
Ammonia Aroma	0.500	0.051
Springiness	0.252	0.104
Firmness	0.263	0.282
Rindcrunch	0.827	1.000
Bitter Flavour	0.302	0.594
Acidic/ Sour Flavour	0.266	0.729
Stickiness of the curd	0.734	0.782
Creamy mouthfeel	0.525	0.397
Smoothness	0.230	0.447

Highlighted cells indicate significant effects (p-value < 0.01)

Outcomes:

- **Table A35** shows that there is a significant judge effect in relation to the *dirty/ stale/ cardboard aroma* attribute (p-value < 0.01). There could be a significant difference between the blind duplicate samples for this attribute; however because of the inconsistency between the judges this can not be determined.