ICE CREAM: AN APPROACH CONSIDERING FORMULATION MICROSTRUCTURE AND EATING BEHAVIOUR

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ABSTRACT

Ice cream is a popular, yet complex, multi-phase/colloidal foodstuff. To understand how this complex microstructure influences the eating behaviour of the consumer requires an interdisciplinary collaboration between Chemical Engineering and Psychology. Thus, an understanding of how product formulation affects consumer preference could be derived and could possibly be used for either product reformulation or promotion.

Experiments explored and quantified the physical properties of the ice cream and how these structures translated into the sensory qualities within the human participants. This involved measuring the consumer's preferences and the potential satiating qualities from different formulations. Destabilisation times of basic emulsions were also examined. The in-depth examination of the eating behaviour of ice cream used an universal eating machine. This showed, that regardless of formulation quality, the rate and total amount consumed remained relatively constant. This counter-intuitive result also persisted over repeated exposures to the product.

By manipulating the physical structure of the ice cream (ice crystal phase through temperature manipulation), an understanding of the limits of oral sensitivity, and consumer perception of an altered product could be gained through a triangle test. These "human" results were contrasted to "machine data" (engineering measurements) gathered in the laboratory. The ice creams differed most markedly in their tribological responses. However, overall, the human panellists were insensitive to these clear physical differences in the test products.

“Begin at the beginning, and go on until you come to the end; then stop”

- Lewis Carroll, Alice’s Adventures in Wonderland

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TABLE OF CONTENTS

CHAPTER 1: Literature Review **1**

1.1 Engineering literature review **1**

1.1.1 What is ice cream? 1

1.1.2 Definition of terms 1

1.1.3 How much is the industry worth? 2

1.1.4 Factors influencing ice cream purchase 3

1.2 The structure of Ice cream **4**

1.2.1 Ice Crystals 4

1.2.2 Fat Globules 6

1.2.3 Air Cells 7

1.2.4 Air destabilisation processes 8

1.2.5 Matrix Phase 10

1.2.6 Creaminess 10

1.3 Ice cream manufacture **11**

1.3.1 Blending 12

1.3.2 Pasteurization 13

1.3.3 Homogenization 13

1.3.4 Ageing 14

1.3.5 Freezing 14

1.3.6 Hardening 14

1.4 Reformulating ice cream **16**

1.4.1 Reducing fat 16

1.4.2 Milk Fat replacements 16

1.4.3 Disadvantages of Milk fat replacements 17
1.4.4 Replacing sugars 18
1.4.5 Introducing more air 18
1.5 Instrumental measurements of ice cream structure 19
1.5.1 Tribology 19
1.5.2 Differential scanning microscopy 21
1.5.3 Rheology 22
1.5.4 Particle size 22
1.6 Eating behaviour literature review 23
1.6.1 Why study eating behaviour? 24
1.6.2 Satiation and Satiety 25
1.6.3 Eating rate 27
1.6.4 Laboratory vs. Free-living 28
1.6.5 Self-reporting measures 28
1.6.6 Measuring intake 29
1.6.7 Effect of palatability and portion size on eating rate 30
1.6.8 Confounding variables in eating behaviour research 32
Chapter 2: Questionnaire And Taste Tests 34
2.1 Ice cream questionnaire study 34
2.1.1 Methodology 35
2.1.2 Results 37
2.1.3 Discussion 48
2.2 Ice cream palatability taste test and portion size test 50
2.2.1 Methodology 51

2.2.2 Results 56

2.2.3 Discussion 61

Chapter 3: Material Properties And Characterisation Of Ice Cream.............. 64

3.1 Material and methods 65

3.1.1 Emulsion preparation 65

3.2 Instrumental measurement methods 69

3.2.1 Particle size measurement 69

3.2.2 Microscopy 70

3.2.3 Creaming Profiles 70

3.2.4 Tribology 70

3.3 Results and discussion 71

3.3.1 Basic emulsions with no e/s mix 71

3.3.2 Microscopy of Shear time experiments 74

3.3.3 Basic emulsions with E/S mix (0.5% and 1%) 74

3.3.4 Influence of emulsifier/stabilizer mixture on creaming profile of emulsions 77

3.3.5 Influence of homogenization on fat particle size of emulsions............... 79

3.3.6 Homogenization on creaming profiles of emulsions 81

3.3.7 Tribology results 83

Chapter 4: Eating Behaviour Investigations 86

4.1 Analysis of commercially available ice cream eating behaviour through a repeated measures design 86

4.1.1 Hypothesis 87

4.1.2 Methodology 87

4.1.3 Results 93

4.1.4 Discussion 103

4.2 Analysis of commercially available ice cream eating behaviour through a Mixed-between Analysis of Variance experimental design 105

4.2.1 Hypothesis 105

4.2.2 Methodology 106

4.2.3 Results 107

4.2.4 Discussion 130

4.3 Additional triangle tests in which commercially available ice creams are manipulated through the process of temperature cycling to alter ice crystal size 132

4.3.1 Hypothesis 133

4.3.2 Methodology 133

4.3.3 Results and discussion 135

Chapter 5: Engineering Investigations 138

5.1 Material and methods 139

5.1.1 Ingredients and nutritional information for commercial ice creams 139

5.1.2 Slumping 140

5.1.3 Rheology measurements 141

5.1.4 Tribology measurements 141

5.1.5 Differential Scanning Calorimetry 142

5.1.6 Particle size analysis 143

5.2 Results and discussion 144

5.2.1 Rhelology measurements 144

5.2.2 Tribology measurements 146

5.2.3 Particle droplet size 150

5.2.4 Differential scanning calormity 152

5.2.5 Meltdown and Slumping 156

5.3 Thesis conclusions and future work 162

Appendix 164

References 198

LIST OF FIGURES

Figure 1.1.: Breakdown of ice cream sale 3

Figure 1.2: Diagram of a dasher.. 4

Figure 1.3: Blending diagram 12

Figure 1.4: Process flow diagram of ice cream manufacutre process.................. 15

Figure 1.5: Tribometer schematic.. 21

Figure 2.1: Photographs of ice cream portion size 55

Figure 2.2: Visual analogue scores for taste tests 59

Figure 3.1: Shear time 1 minute 73

Figure 3.2: Shear time 5 minutes 73

Figure 3.3: Shear time 10 minutes 74

Figure 4.1: Mood ratings pre/post sessions 95

Figure 4.2: Palatability VAS ratings 96

Figure 4.3: Engery density of ice creams 97

Figure 4.4: Average rate of intake 99

Figure 4.5: Within meal Enjoyment 102

Figure 4.6: Within meal hunger 102

Figure 4.7: Within meal Fullness 103

Figure 4.8: Palatability VAS ratings across 3 sessions Sainsburys 114

Figure 4.9: Palatability VAS ratings across 3 sessions Mackies 114

Figure 4.10: Palatability VAS ratings session 1 115

Figure 4.11: Palatability VAS ratings session 2... 115

Figure 4.12: Palatability VAS ratings session 3... 116

Figure 4.13: Average overall intake for 3 sessions 117

Figure 4.14: Average ED over three sessions 119
Figure 4.15: Rate of intake session 1 121
Figure 4.16: Rate of intake session 2 121
Figure 4.17: Rate of intake session 3 122
Figure 4.18: Within meal enjoyment VAS ratings over quartiles 126
Figure 4.19: Within meal hunger VAS ratings over quartiles 128
Figure 4.20: Within meal fullness VAS ratings over quartiles 130
Figure 5.1: Schematic of tribometer 142
Figure 5.2: Rheological measurments 145
Figure 5.3: Sainsburys normal and Sainsburys cycled tribometre data 147
Figure 5.4: Mackies normal/cycled tribometer results 148
Figure 5.5: Sainsburys normal/cycled vs Mackies normal/cycled tribometer results 148
Figure 5.6: Particle size for normal and cycled samples 152
Figure 5.7: Heating/melting point of ice creams 155
Figure 5.8: Cooling/freezing point of ice creams 156
Figure 5.9: Slumping of ice creams over time 158
Figure 5.10: Slumping of ice creams at 37°c over time 160

LIST OF TABLES

Table 2.1: Smoke/diet/health ... 39

Table 2.2: Do you eat ice cream? ... 40

Table 2.3: Frequency of eating ice cream ... 40

Table 2.4: Where do you purchase ice cream? ... 41

Table 2.5: Brand purchase ... 42

Table 2.6: Ice cream texture preference ... 42

Table 2.7: Types of ice cream consumed ... 43

Table 2.8: Method in which ice cream is consumed ... 44

Table 2.9: When ice cream is consumed ... 45

Table 2.10: Factors influencing ice cream purchase ... 46

Table 2.11: Ice cream brand association ... 47

Table 2.12: Ice cream brand association ... 47

Table 2.13: Ice cream quality ... 48

Table 2.14: Ice cream composition ... 53

Table 2.15: Descriptive statistics for taste test 1 ... 57

Table 2.16: Descriptive statistics for taste test 2 ... 58

Table 2.17: Descriptive statistics for highest scoring premium and basic ice creams ... 60

Table 2.18: Portion size exercise ... 60

Table 3.1: Basic emulsion no emulsifier/stabliser mix ... 66

Table 3.2: Basic emulsion (0.5% emulsifier/stabliser mix) ... 66

Table 3.3: Basic emulsion (1% emulsifier/stabliser mix) ... 67

Table 3.4: Homogenised samples ... 68

Table 3.5: Commercially avaliable ice creams 69

Table 3.6: Particle size (Voulme/weight) for basic emulsions no e/s mix 72

Table 3.7: Particle size (volume/weight) for basic emulsions 0.5% and 1% e/s mix 75

Table 3.8: Creaming profiles of 0.5% e/s mix on basic emulsions 77

Table 3.9: Creaming profile for 1% e/s mix on basic emulsions 77

Table 3.10: Particle size (volume/weight) Homogenised 30% fat basic emulsion 80

Table 3.11: Homogenisation on creaming profiles of 30% fat emulsions 81

Table 4.1: Age/BMI/DEBQ results 88

Table 4.2: Nutritional composition of ice creams 89

Table 4.3: Mood ratings pre session 93

Table 4.4: Mood ratings post session 94

Table 4.5: Palatability ratings 96

Table 4.6: Average rate of intake 98

Table 4.7: Pre meal hunger/fullness ratings 99

Table 4.8: Within meal data in quartiles 100

Table 4.9: Age/BMI/DEBQ scale 106

Table 4.10: Pre session mood ratings (sessions1/2/3) 110

Table 4.11: Post session mood ratings (session1/2/3) 111

Table 4.12: Palatability ratings across 3 sessions 112

Table 4.13: Average amount of ice cream consumed over 3 sessions 117

Table 4.14: Engery density cosumed over 3 sessions 118

Table 4.15: Rate of intake over 3 sessions 120

Table 4.16: Pre session enjoyment/hunger/fullness VAS ratings 123

Table 4.17: Descriptive statistics for enjoyment VAS scores over quartiles........ 125

Table 4.18: Descriptive statistics for hunger VAS ratings over quartiles............ 127

Table 4.19: Descriptive statistics for fullness over quartiles................................ 129

Table 4.20: Triangle test results 135

Table 4.21: List of descriptors used by participants 136

Table 5.1: Composition of ice creams 140

Table 5.2: Particle size (Volume/weight) for normal and cycled samples 151

Table 5.3: Heating peak analysis of thermal properties of ice cream.................. 154

Table 5.4: Cooling peak analysis of thermal properties of ice cream 154

Table 5.5: Representative photographs of ice cream samples at 25°c 157

Table 5.6: Representative photographs of ice cream samples at 37°c 159

SUMMARY OF THESIS

Chapter 1: Literature reviews encompassing areas of engineering (formulation) and psychology (eating behaviour) regarding the nature of ice cream formulation through laboratory-based data and eating behaviour, leading to discussion on satiation and satiety.

Chapter 2: Questionnaire and taste test experiments of a variety of commercially available ice creams with human participants.

Chapter 3: Investigations into ice cream to better understand time scales of destabilisation and material change, gathered from preliminary experiments, such as basic emulsions and creaming profiling.

Chapter 4: Eating behaviour investigations

Separated into three sections for ease of reading:

4.1: Analysis of commercially available ice cream eating behaviour through a repeated measures design

4.2: Analysis of commercially available ice cream eating behaviour through a Mixed-between Analysis of Variance experimental design

4.3: Additional triangle tests in which commercially available ice creams are manipulated through the process of temperature cycling to alter ice crystal size.

Chapter 5: Formulation analysis of commercially available ice cream studied in Chapter 4 through the use of engineering methods and thesis conclusions.

CHAPTER 1: LITERATURE REVIEW

1.1 Engineering literature review

1.1.1 What is ice cream?

Ice cream is a commonly consumed frozen dessert, the term of which is used to cover a broad range of different types. These range from dairy ice creams, which are a frozen aerated mixture of diary ingredients sugars and flavours, to sorbets, which are fruit based aerated sugar syrup solutions that contain neither fat nor milk.

1.1.2 Definition of terms

The legal definition of an ice cream varies from country to country. In America, for a product to be called an ice cream, the product must contain no less than 10% milk fat, and Canada, no less than 8% (Goff & Hartel, 2013). However, in the UK, the industry is a little more complicated, with several categories of ice cream being available to consumers. For a product to be legally named an 'ice cream' the definition is as follows:

'Shall not be applied to any food other than frozen product containing not less than 2.5% milk protein, not necessarily in natural proportions and which is obtained by subjecting an emulsion of fat, milk solids and sugar, with or without the addition of other substances, to heat treatment and either to subsequent freezing or evaporation, addition of water and subsequent freezing.' (Food Labelling regulations, 1996)

A ‘Dairy ice cream’ has the following definition:

‘Shall not be applied to any food other than one which fulfils the conditions relating to application of the description “ice cream” to a food (provided that the fat in respect of which a minimum 5% is specified shall here consist exclusively of milk fat) and which contains no fat other than milk fat or any fat present by reason of the use as an ingredient of such ice cream of any egg, any flavouring or any emulsifier or stabilizer.’ (Food Labelling regulations, 1996)

1.1.3 How much is the industry worth?

The global market for ice cream is estimated to be worth £35 billion, with the USA accounting for £13 billion and the UK £1.48 billion, and the largest producers of ice cream are Unilever and Nestle, which in unison hold 29% of the market share (Clarke, 2008). The USA is the largest producer of ice cream, producing around 6 billion litres per annum and has a per captia annual consumption of 18.3 Litres. In the UK the consumption rate is lower, with the average person consuming 6 litres (Stones, 2012)

In practice, this indicates that the global desire for ice cream is huge, and the market is constantly evolving, seeking new and exciting products to sell to the consumer. It may also indicate that there is scope for new and improved healthy formulations with the ever-growing obesity epidemic that is sweeping the globe. However, it is imperative that these formulations, whilst improving on health, do not compromise on taste and texture.

1.1.4 Factors influencing ice cream purchase

There are several factors that influence the consumer to buy ice cream, none more so than time of year and the type of ice cream they wish to purchase. Demand for impulse purchases is highly seasonal in the UK. It is estimated that sales in the summer months can be as much as five times higher than in the winter months (Goff & Hartel, 2013; Clarke, 2008). Boniface & Umberger (2012) found that in Malaysia, ice cream was purchased most frequently, with 34% of the cohort tested purchasing it weekly. It was hypothesised that this may be due to the increase in the amount of supermarkets now present in Malaysia, which is where most of the subjects purchased the ice creams

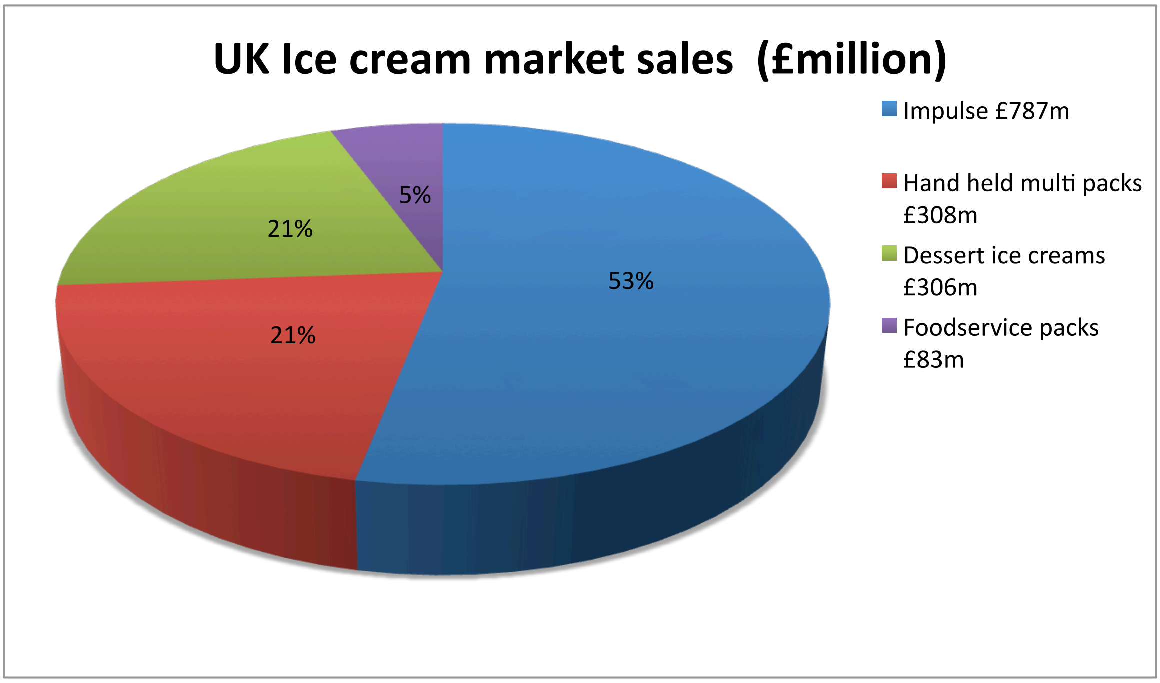


Figure 1.1: Breakdown of ice cream sale

1.2 The structure of Ice cream

The structure of ice cream is highly complex and of great importance to the perception of in mouth texture when it is consumed (Varela, Pinter & Fiszman, 2014). This complex structure is formed during the aeration and freezing processes. The structural phases of ice cream include ice crystals, fat globules, air bubbles and a serum phase known as the matrix consisting of sugars and stabilizers. Please see appendix for a detailed diagram of the microstructure of ice cream.

1.2.1 Ice Crystals

This discrete phase is formed by secondary nucleation in a scraped surface freezer. Diagram 1.2 is a cross section example of a scraped surface freezer used in the manufacture of ice cream and integral to the formation of ice crystals. Please see page 14 for more detail.

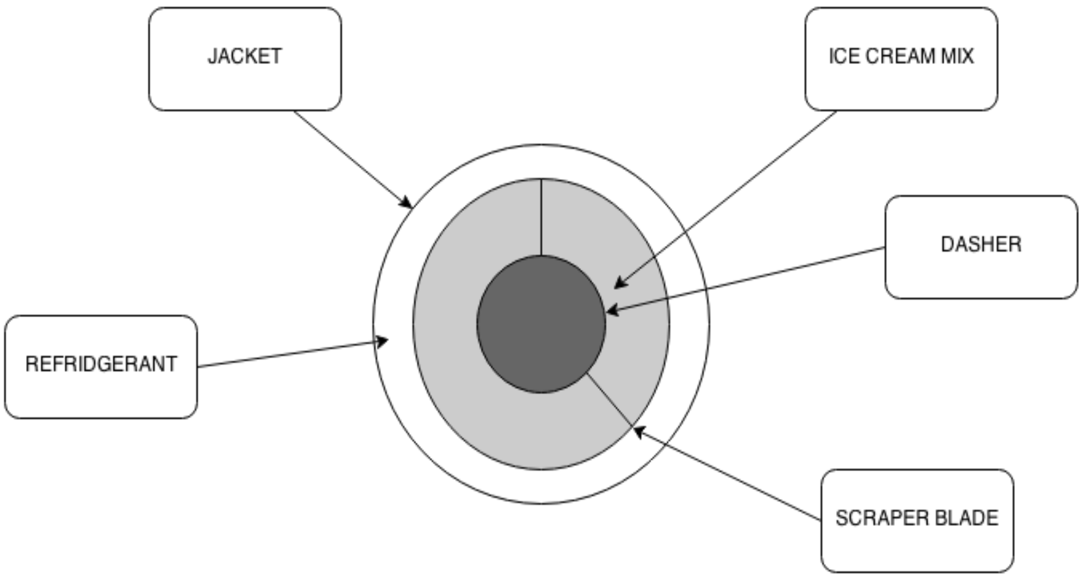


Figure 1.2: Diagram of a scraped surface freezer

Ice crystals can vary in size from 1µm to 150µm (Cook & Hartel, 2009). It is vital to the mouth feel and texture of the ice cream that the sizes of the ice crystals are small, with a diameter of no more than 50µm, preferably around 35µm, for limited detection. Above this, the ice crystals will be detected in the mouth and the ice cream will have a gritty mouth feel (Marshall *et al* , 2003). The desired quality of an ice cream is to have small ice crystals to give a smooth and palatable texture. It is therefore vital to control the rate of crystallization in order to develop ice crystals with correct size, shape and distribution qualities. This can be achieved during the nucleation freezing process, which takes place during the freezing stage of manufacture (Clarke, 2008). In order to produce small ice crystals, the nucleation must take place at a low temperature. The shorter time the ice cream mixture is present in the freezer, coupled with slower dasher speeds also aid in producing ice crystals with smaller mean size. This is the reason that Freon and ammonia are used as a jacketed refrigerant in the freezing process, as it promotes rapid nucleation (Goff, 1995). The whipping process also allows the ice crystals to remain discrete.

Re-crystallisation is the process of changes in the ice crystal size and distribution due to temperature change during storage (Goff, 1997). The effect of re-crystallization on ice crystal size and distribution is important; as this can alter the microstructure leading to an ice cream with a coarse mouth feel. Re-crystallization occurs via two mechanisms: Ostwald ripening and accretion. Water vapour can also alter the ice crystal structure (Clarke, 2008). There has been recent research into trying to overcome the issue of re-crystallization (Clarke, Buckley & Lindner, 2002; Goff & Regand, 2006).

When an ice cream melts in the mouth, the structural elements change, as the ice melts and the fat stabilized foam structure collapses. The outside temperature and also the rate of heat transfer affect the rate at which the ice melts. However, this cannot occur until the fat stabilized foam collapses, which is a function of the partial coalescence of the fat globules.

1.2.2 Fat Globules

The fat structure is formed during homogenization in the manufacturing process, and is vital to stabilizing the air phase of the formulation (Clarke, 2008).

During homogenization a pre-emulsion is formed by dispersing molten liquid fat in order to obtain droplet sizes below 2μm (Eisner *et al* ., 2007). However, research has indicated that the role of pasteurization also helps to melt the fat in order to create a well-homogenized fat emulsion (Marshall & Arbuckle, 1996). Following high-pressure homogenization, discrete and partially coalesced fat droplets are present in both the matrix phase and at the surface of the air phase. High-pressure homogenization (200atm) and double homogenization can produce smaller fat droplets allowing for an increased fat surface area (Clarke, 2008). This is beneficial in low fat ice cream mixes as the air bubbles become more stable.

The emulsifiers control the structure of these fat globules and the degree of the partial coalescence in the system. Emulsifiers are added to the ice cream mix to increase the stability of the fat emulsion during freezing, and improve desirable qualities in the ice cream such as whipping ability and allow for a slower meltdown (Baer, Wolkow & Kasperson, 1997;Goff 1997). Meltdown rate can be described as the rate at which the ice cream melts, which can be heavily influenced through the ingredients used in the ice cream. Also, the type of emulsifier, such as lecithin found in egg yolks, or Polysorbate 80 and level of incorporation used can impact on the partial coalescence (Goff, 1997;Davies ,Dickinson & Bee, 2000). Generally, according to Tharp & Young (2012), in higher fat ice creams, lower levels of emulsifier are needed. Above a fat content of 15% no emulsifier is usually required. Polysorbate 80 has a restriction of incorporation at around 0.06% due to it potential to taint flavour. Mono dygliceride/Polysorbate blends are common to address this problem (Tharp & Young, 2012), as are stabiliser and emulsifier blends. The concentration of the total solids of the ice cream influence the amount of the blend that can be incorporated into the ice cream mix, and also depends on the type of ice cream desired i.e. soft serve or low fat. Typical levels of emulsifier/stabiliser blend are between 1% (non fat ice creams) and 0.4% (soft scoop ice creams) (Naresh & Merchant, 2006)

Fat has a profound impact upon flavour and mouth coating of ice creams. Some volatiles are soluble in oil and not in water and the solid fat particles allow an increase in viscosity of the matrix phase, which contributes to a decreased meltdown rate (Koxholt, 2001).

1.2.3 Air Cells

As ice cream is both an emulsion and foam, the size and distribution of air cells play a vital role in the structure of ice cream (Ronteltap & Prins, 1990). It is also intrinsic to the sensorial aspect of creaminess, a heavily desirable quality of ice cream (Wildmoser Sheiwiller & Windhab, 2004), with smaller bubbles sizes producing a more pronounced sensation of creaminess. Defining ‘creaminess’ is complex, and defining human sensitivity to creaminess is even more complex. It is generally accepted that creaminess has a hedonic level and is a key component of sensory appeal, especially in foods such as ice cream and yoghurt (Folkenberg & Martens, 2003). Kokini (1987) suggested a relationship between thickness as a shear stress on the palate. The perception of creaminess is a function of smoothness and thickness, which is related to rheological properties (Frost & Janhoj,2007). Air is incorporated into the mixture during the freezing stage in the scraped surface heat exchanger, and small air bubbles (around 20-80μm in diameter) are produced. The fat droplets are vital to the air interface, and during the freezing and aeration of the mix, the homogenized milk fat emulsion undergoes partial coalescence, causing the fat droplets to cluster and aggregate, which then form around the air bubbles and stabilize them.

1.2.4 Air destabilization processes

The purpose of air in ice cream is to soften it. Without air, it would be hard and inedible. The air phase also allows for light to scatter, affecting colour and appearance, and also hinders the separation of ice crystals reducing the risk of accretion, such as Ostwald ripening (Clarke, 2008).

There are two coarsening mechanisms that involve the air cells in ice cream: Disproportionation and coalescence. These two mechanisms are somewhat interconnected, due to the rate of one on another (Walstra, 1996). Disproportionation is analogous to Ostwald ripening of ice crystals; the Laplace pressure inside an air bubbles is larger than that of the outside. The smaller the bubbles the larger the pressure, hence there is a net transfer of air from the smaller bubbles to the larger, causing the smaller bubbles to disappear. Coalescence occurs when two bubbles come into contact and the film separating them ruptures.

A way of inhibiting disproportionation is increasing the viscosity of the matrix phase (Sofjan & Hartle, 2003). This increased viscosity reduces the rate of diffusion between bubbles, eliminating disproportionation. The absorption of emulsifiers at the bubble surface interface reduces coalescence by lowering the surface tension (Clarke, 2008)

Overrun is the measurement of air whipped into the ice cream mix during freezing and is calculated as a percentage increase of the finished product. For example, 1 litre of ice cream mix post whipping and freezing may yield 1.5 litres of finished product, therefore, the overrun is 50%. Hartel (1996) stated that low overrun causes coarser ice crystal formation compared the same formulation made with a higher overrun. This is because the air cells may aid the impediment of ice crystals during freezing. Flores and Goff (1999) suggested that a low amount overrun does not influence ice crystal size and but that around 70% is necessary to have a noticeable impact on microstructure. However when the volume of air reached critical volume, increasing overrun had less impact on the overall ice cream structure.

An excess in overrun can have a negative impact on ice cream quality: too much air will dissipate flavour and produce ice cream that is fluffy in texture and light in weight (Porto, 2012).

1.2.5 Matrix Phase

This is a highly viscous freeze concentrated continuous serum phase in which the air bubbles, fat globules and ice crystals are embedded. Containing a solution of dissolved colloidal sugars, proteins and stabilizers, the concentration of these solutes is considerably higher than that of the mix due to 75% of the water in the mix being frozen. (Clarke, 2008). The matrix phases also lends itself in aiding the mouth feel of the ice cream. Due to the water in the phase becoming frozen in the form of ice crystals the concentration of the dissolved sugars and stabilisers in the matrix phase will aid in determining the viscosity of the ice cream (Vega *et al* , 2013).

1.2.6 Creaminess

As previously mentioned, ‘creaminess’ is often one of the most popular terms in which to describe ice cream, particularly relating to it’s quality. But creaminess is such a multifaceted term, that it can be very complex to try and understand (Frost & Janhog, 2007). Before being able to understand it as a sensory perception, creaminess can relate to a physical and chemical relationship, which can be measured instrumentally through methods such a rheology and tribology (see later sections). It then moves into human interactions between ‘sensory modalities’ such as vision, olfaction etc, and finally, trying to understand creaminess relating to oral processing and the breakdown of food.

Ice cream is often judged on being ‘creamy’ before it has even been consumed, often related to its colour, the presence of vanilla seeds and advertising. It is not until the ice cream actually beings to destabilize in the mouth with the breakdown of its structure that human perception of creaminess takes place. Brockhoff (2001) found that overall, creaminess can only be moderately predicted through the use of instrumental measurements such as rheology. But others have found that this is dependent on the type of food being tested. Weak gels, such as yoghurts, cannot have their creaminess predicted accurately when compared to other dairy products such as cream cheese (Janhoj, Petersen *et al* , 2006; Janhoj, Frost & Anderson, 2006)

1.3 Ice cream manufacture

Ice cream is a complex polyphasic system that comprises of ice crystals, fat globules, air bubbles and an unfrozen serum phase known as the matrix. These individual phases when combined provide the properties of the underlying microstructure to an ice cream. Ice crystals and air bubbles usually range between 20-50µm, whilst the air bubbles are partially coated with fat droplets, which themselves are coated with an emulsified layer. The matrix phase consists of sugars and polysaccharides in a freeze concentrated solution. Structural development then continues during manufacturing processes such as blending, pasteurization, homogenization, aging, freezing and hardening (Clarke, 2008).

These manufacturing processes are vital to the development and stability of the microstructure. Generally the manufacturing can be broken down into two stages: Mix preparation and freezing operations (Clarke, 2008; Marshal *et al* l, 2003). The mixing preparation consists of blending ingredients, batch or continuous pasteurization, homogenization, cooling and aging. The freezing operations then begin once the mixture has aged. This creates two discrete phases, millions of tiny air bubbles and ice crystals are dispersed into the concentrated mix via batch or continuous freezing, and then the ice cream is packaged, left to harden and then stored, ready to be distributed. Below is a brief description of each of the manufacturing stages. Please see Figure 1.4 for an overall process flow diagram of ice cream manufacture.

1.3.1 Blending

Once the desired formulation has been decided, and ingredients selected and weighed, the first step consists of blending the ingredients in a tank to produce what is known as the ice cream mix. These tanks have mixers and agitators, which allow powders to be incorporated and mixed together with liquid ingredients, at very high speed (Tharp & Young, 2012). Dry ingredients can include whey powder, flavourings and emulsifiers and stabilizers, whilst the wet ingredients can include water, cream, and melted vegetable oils or other fats.

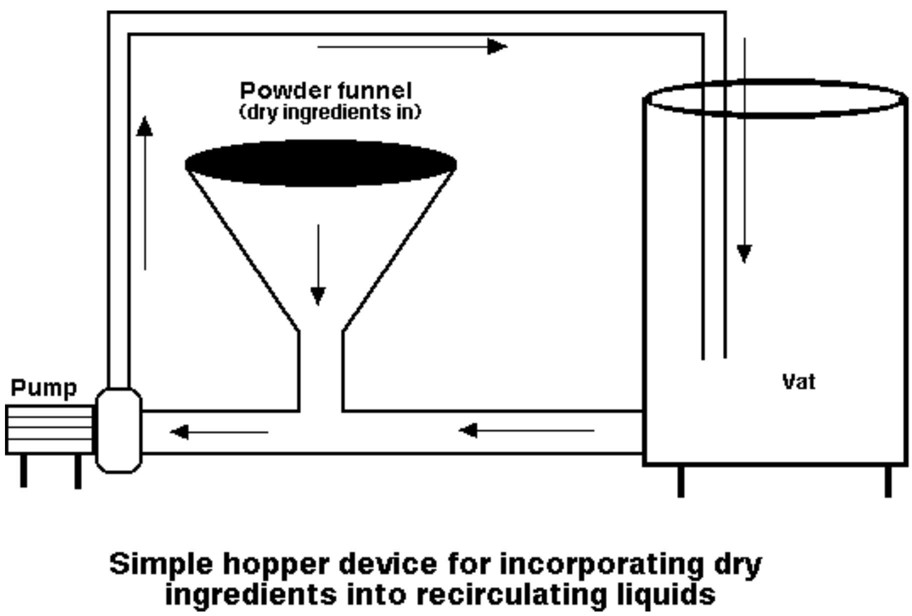


Figure 1.3: Blending diagram (Source: University of Guelph)

1.3.2 Pasteurization

Once blended, the mix then goes on to be pasteurized. This reduces the number of microorganisms to a level that is acceptable and safe for human consumption. Pasteurization can differ from manufacture to manufacture and also country to country, depending on the health and safety laws. For example, in factories in America, the pasteurisation of their mix takes place at HTST (high temperature and short time), which equates to the ice cream mix being heated to 83 °C for 20 seconds (Heuer, 2009). However, the mix should not exceed 85 °C as this will negatively affect the milk proteins present. (Clarke, 2008)

1.3.3 Homogenization

Homogenization then takes place. The hot pasteurised mixture is pressurised through a small valve at 2000psi and this causes the large fat droplets present in the mix to become broken up and a fine emulsion is produced. These smaller fat droplets (usually 1μm or less in diameter) lead to a greater surface area of fat for the given volume. A two stage homogenization is preferred with ice cream mixes (Rajah, 2002) as this reduces clumping and clustering of the fat, leading to an improved thinner emulsion, which aids meltdown rate and creates better air stability. The main purpose of the homogenisation step is reduce the size of the flat globules (to around 2μm) resulting in the greater stability of the fat during ageing (Biasutti *et al* , 2013)

1.3.4 Ageing

Once the pasteurised and homogenisation mix has been cooled (usually via re circulation to a cooling tank where it is cooled to 4°C which inhibits bacterial growth) it is pumped into ageing tanks. Here, the mix remains for between 4-24 hours. (Marshall *et al* , 2003). The purpose for ageing the ice cream mix is three fold as it improves whipping capabilities of the ice creams, leading to a smoother overall product by:

- Providing time for fat crystallisation
- Allow emulsifiers to absorb to the fat droplets
- Increased viscosity by allowing protein hydration (Goff, 1997)

1.3.5 Freezing

Following time in the ageing tank, the mix then processed using a continuous freezer or ‘barrel’ freezer at between -18 and -22 °C. There are rotating blades inside the barrel, which scrape off the surface of the freezer and ‘dashers’ (see Figure 1.2) which help incorporate air into the mixture by constant whipping of the mix. The mix is often pumped in at a constant rate as well as a constant supply of air being pumped in. This air is what gives the ice cream its softness, and the air content of ice cream is often termed ‘overrun’. The ice cream is then ready to be extruded, where it is packaged and sent to be hardened (Goff, 2011).

1.3.6 Hardening

Once packaged, the ice cream is sent to be hardened by being placed into a blast freezer (-30/-40 °C) and freezing rates must be rapid to affect the rate of heat transfer, which impacts on the final ice cream product. The purpose of hardening is to remove heat at quickly as possible from the ice cream (Hui, 2006) in order to inhibit the ripening/recrystalization of the ice crystals. Certain factors that can influence this are:

- Temperature of the blast freezer
- Size and container type
- Temperature of ice cream when placed in the blast freezer
- Air circulation of the blast freezer

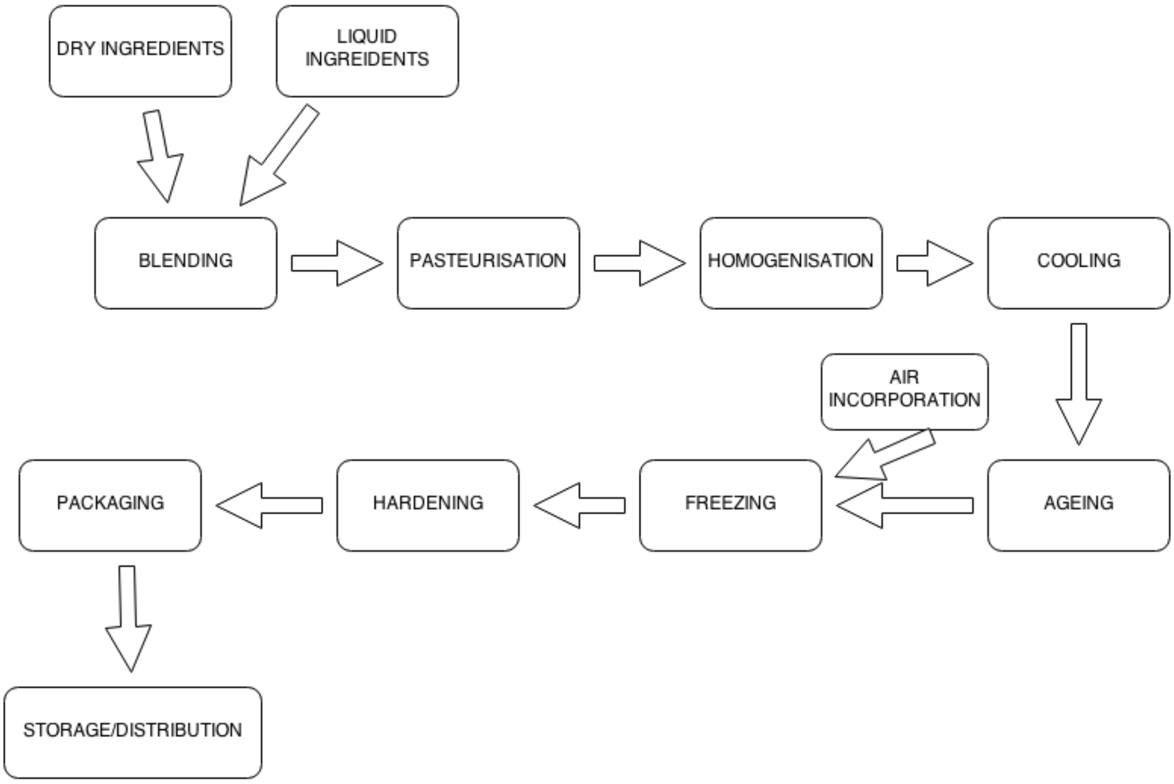


Figure 1.4: Process flow diagram of ice cream manufacture process (Redrawn from University of Guelph)

1.4 Reformulating ice cream

1.4.1 Reducing fat

Fat is vital to the structural and sensorial properties of ice cream. The fat in dairy products increase richness of flavour, carries flavour compounds, allows for lubrication of the palette, aids the desirable melting properties and provides structure for foam stabilisation (Marshall, Goff & Hartle, 2003). Whilst premium ice creams contains between 10-18% fat, low fat alternatives are now being sought out by consumers. However, consumers still wish to have all the perceived and sensory qualities of a premium full fat ice cream, as was seen in Yilsay *et al* (2005) study into fat replacers. Results emphasised the importance of fat as a flavour enhancer.

Fat in dairy ice creams come from milk fat, such as cream, buttermilk and anhydrous milk fats (Marshall *et al* , 2003). It is the volatile fatty acid chains of the triglycerides in the milk fat that lead to the flavour of milk fat, and allows for a wide melting range. (Goff, 2008). This melting range causes the ice crystals to melt and the fat stabilised foam structure to collapse. When this occurs in the mouth, it aids the mouth coating properties of the ice cream, leading to an increased sensation of creaminess.

1.4.2 Milk Fat replacements

Alternatives to milk fat used in ice cream production in the UK are commonly vegetable fats. However, the vegetable fats used need to replicate the melting profile of the milk fat ice cream, as fats that melt at higher temperatures leave a waxy and 'claggy' mouth feel and those with a low melting point are unable to maintain the foam structure (Clarke, 2008). Vegetable fats that have been used in ice creams include palm oil, and coconut oil. Goff (2007) found that vegetable fat was acceptable to the consumer in the production of ice creams when substituted milk fat either partially or completely with vegetable fats. These fats administered a clean flavour, crystallised rapidly and contributed positively to the overall structure. It was concluded that the most suitable blends came from a formulation of 5% fractionated palm kernel oil and 25% high oleic sunflower oil. Proteins such as whey, or carbohydrates such as microcrystalline cellulose can be used in low fat ice creams to mimic fat droplets (Clarke, 2008) but cannot completely reproduce the same mouth feel as milk fat.

1.4.3 Disadvantages of Milk fat replacements

Whilst there are many health benefits to replacing milk fat in ice cream with alternative fats, there are also structural and chemical disadvantages that must be overcome to produce a viable product. Some vegetable fats can leave a waxy and unpleasant mouth feel (Goff, 2007) and also the fat globule phase can become disrupted, which impacts upon the structure (Aime *et al* , 2001). Schmidt *et al* (1993) found that the use of carbohydrate based fat replacers in low fat ice creams produced mixes with a greater viscosity, and incorporated much less air into the mixes. Adapa *et al* (2000) found that milk fat replacements increased the viscosity of mixes yet lowered the elasticity, and concluded that rather than replacing milk fat with one product alone, a balanced mixture of fats, carbohydrates and proteins were needed to maintain the delicate and complex structure of ice cream.

1.4.4 Replacing sugars

Sugar has several vital functions in ice cream: Not only does it give the product a sweet flavour and desirable taste and it affects the viscosity of the matrix phase, but it also depresses the freezing point of the matrix phase (Clarke, 2008). Commonly used sugars include sucrose. By manipulating the quantity and type of sugar, a harder or softer ice cream can be produced. Literature has indicated that polyols may be used as a sugar replacement in ice cream formulation (Bordi *et al* , 2004). Polyols are sugar alcohols that still structurally resemble sugars, but have the advantage of lower a calorific value when compared to sucrose and a reduced insulin response (Livesey, 2003;Zumbe, Lee & Storey 2001). However, Koutsou *et al.* (1996) and Clarke (2008) have both documented that the use of polyols in food can lead to gastro enteric problems when consumed in large amounts.

1.4.5 Introducing more air

Dressaire *et al* (2008) describes incorporating more air into an ice cream mix may be a way to increase the volume of ice cream without adding caloric value. The incorporation of air is vital to the overall eventual microstructure of the ice cream, and the smaller the air bubbles, the more palatable it is to the consumer. It therefore would be beneficial to consider the use of micro bubbles in ice cream. The use of micro bubbles, which can be described as bubbles smaller than 1mm in diameter, in foods has lead to research that indicates improved and longer shelf life of products.

1.5 Instrumental measurements of ice cream structure

Instrumental measurements of a complex muti-phasic food such as ice cream is complicated. From an engineering stance it is desirable to take instrumental measurements to gain a better understanding of structure. But with food, this is not possible due to psychological impact of innate liking. It is vital to understand the physical interaction between the structure and the mechanisms used to break this down, and how this can be related back to human perception and interaction with food. For example, with regards measuring 'creaminess' a combination of both static and dynamic process is recommended (Frost & Janhog, 2007)

1.5.1 Tribology

Tribology (or thin film rheology) can be described as the science of friction and lubrication and whilst most commonly used in metal processing, has been used to correlate in mouth responses to food (Malone *et al* , 2003). This study of friction and lubrication between interacting surfaces in relative motion, and the number of interacting surfaces in the mouth during food consumption is plentiful: teeth–teeth, tongue–palate, tongue–teeth, teeth–food, tongue–food, tongue–bolus, lips, lips–food, bolus–palate, food particles–oral surfaces (Stokes, 2013). A tribometer works by measuring the friction and wear between two surfaces. These surfaces often consist of a flat surface (the disc) and a spherical surface (the pin) repeatedly moving across each other with a material between them. Extensive detail on tribology fundamentals and food lubrication can be found in a recent review on 'oral tribology' (Stokes, 2012). Malone *et al* (2003), who use guar gum to correlate friction measurements with perceived lubrication in mouth, hypothesised that two mechanisms may be involved in explaining the reduced friction with highly vicious fluids. These were the presence of a polymer layer in the contact area prohibits the surface from contacting and that the high viscous guar gum limits drag through turbulent flow suppression. Dresselhuis *et al* (2007) demonstrated an inverse relation between fat perception and in mouth friction sensed between the tongue and the palate. Evidence also suggested that oil in water emulsions, which have an increased sensitivity to coalescence, give rise to a lower friction rate, both in measurement and oral perception, which leads in enhanced fat perception. Malone *et al* (2003) and De Wijk and Prinz (2003) concluded that friction could be closely associated with fat texture attributes in mouth. However, eating and chewing is a dynamic process. These studies were all conducted with the use of artificial surfaces. They fail to take into account the 'oral mucosa' of human in mouth conditions, which can be a limitation of tribology measurements and relating these back to actual sensory perception. There is great debate within academia as to the reliability of such a technique. Recently, Van Aken (2013) revealed a potentially new method of measuring in mouth conditions, known as 'acoustic tribology'. It involves taking a tiny microphone and placing it in the participant's mouth in order to record the acoustic signals produced by their tongue rubbing against the palate.

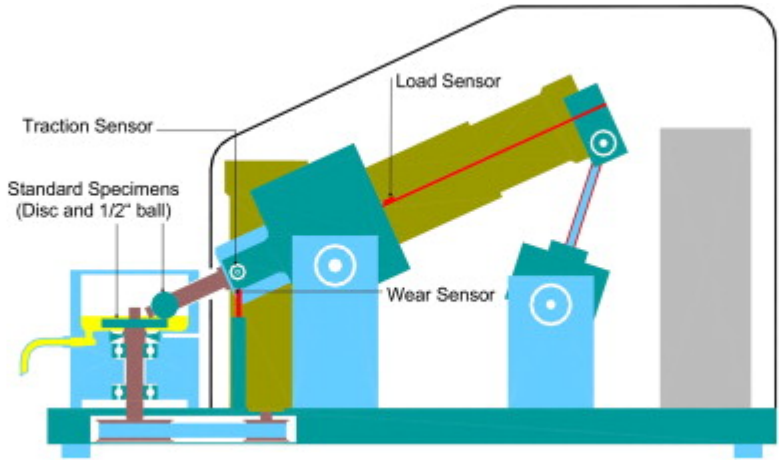


Figure 1.5: Tribometer schematic

1.5.2 Differential Scanning Calorimetry

Differential scanning microscopy is the most widely used method to determine specific heat and enthalpy data of food materials. The technique is based on differential heat flow measurements between an empty reference pan and sample pan, and is used to measure the difference in the amount of heat required to increase the temperature of the sample and reference is measured as a function of temperature. Cogne *et al* (2003) found that the main advantages of the DSC rely on rapid and simple measurement obtained by a single 'thermo-gram'. However, sample sizes are minute and care and attention is needed when carrying out experiments accurately with the DSC. Sastry & Datta (1984) found that when conducting studies into commercial ice creams thermal conductivity depended greatly on the ice cream density. Goff *et al* (1993) found that during storage, ice cream and suffer ice crystal growth and structural collapse and that these detritions become more prevalent with higher freezer temperatures, increased storage time and greater temperature fluctuations.

1.5.3 Rheology

Rheology is the study of two material properties such as an elastic solid and a vicious liquid (Schmidt, 2000). The behaviour of these 'visco elastic' substances is measured by applying a controlled amount of shear stress or strain to a sample and measuring the response of the sample. Goff *et al* (1995) found that ice cream mixes with stabilisers exhibited longer storage and loss module at temperatures of less than -8°c. Authors such as Subramanian *et al* (2006) and Adapa *et al* (2000) concluded that fat reduction in dairy products resulted in increased visco-elastic properties and that the amount of fat and degree of fat destabilization affected the elasticity. Adapa *et al* (2000) also found that fat replacers (both protein and carbohydrate based) did not enhance the elastic properties but did increase the viscosity of frozen ice cream mixes.

1.5.4 Particle size

The particle size of fat droplets present in food emulsions such as ice cream mixes is vital in defining properties such as flavour release, mouth feel and emulsion stability. Large droplets can lead to poor flavour release, greasy mouth feel and poor emulsion stability leading to creaming. Using a particle size analyzer such a mastersizer is an excellent tool for measuring characteristics of food emulsions. With wide dynamic range (0.02-2000µm) it permits both fine emulsion droplets and larger flocculated or coalesced droplets to be characterized. This range also allows for the measurement of large protein micelles, such as casein, enabling the interaction between the protein and emulsified fat phase to be understood. (Malvern instruments 2013). Koxholt (2001) investigated the effect of fat globule size on the meltdown of ice cream, and found that meltdown was dependent on fat agglomerate size in the unfrozen serum phase.

1.6 Eating behavior literature review

Literature shows that people develop expectations about the taste and effects of certain foods and that those expectations can guide future behaviour, cognitions, and affect (Bowen *et al* , 1992). Certain characteristics of food, such as its energy density, can be indicators of perceived satiety. If these characteristics of foods, such as the energy density of ice cream, can be manipulated through formulation, this may have an impact on the perceived satiety and perceived satiation of the product. Therefore, understanding the phenomena of the human appetite has become a vital tool in trying to combat obesity and advocating a healthier lifestyle (Blundell *et al* , 2009). The selection of foods, its optimal consumption rates and amounts is central to the regulation of body weight. This has become increasingly necessary to enable accurate measurement of appetite and eating behaviour under differing conditions.

Eating behaviour is controlled by numerous factors and includes internal physiological signals and external signals that may arise from social factors, cultural rules, as well as cognitive cues (Rodin, 1992). In 1922, Richter first demonstrated this in rats. He found that when he recorded each time they ate, it revealed their circadian rhythm of 12 meals a day. Le Magnen (1973) then went to on to show that analysis of such meal patterns in rats could show the operation of hunger and satiety processes. Eating behaviour can also be described in terms of macrostructure and microstructure (Elfhag *et al* , 2003). The microstructure[1] of eating refers to how an individual eats within the framework of one single meal and can be measured and studied experimentally by eating monitors. The macrostructure of eating refers to what is consumed over a long period of time and the manner in which it is consumed.

1.6.1 Why study eating behaviour?

The importance of laboratory based investigations into eating behaviour cannot be stressed enough. The ever-expanding problem of obesity in the Western world highlights the need to better understand eating behaviour, particularly in the UK and the US, where obesity levels are at an all time high (Royal College of Physicians, 2010). There are also other reasons for controlled studies of eating behaviour. For instance, in the development of 'functional foods' for appetite control, and the reformulation of current market products to become 'healthier'. Also, the impact of anti-obesity drugs may have on eating behaviour (Blundell, 2006) has and will need to be assessed. Under these circumstances, a precise assessment of eating behaviour, food intake, rate of intake, satiation and satiety, is essential to define and support the efficiency of the food or drug. In the case of analysis, eating rate and its cumulative intake curves has been shown to be useful

[1] There is a difference between the disciplines, engineering and psychology, with the use of the term 'Microstructure'. It is important to point differentiate between the two, and within this document, the term microstructure is used to describe formulation, rather than the psychological use to describe eating behaviour.

in detecting both the effects of experimental manipulation and individual differences in eating behaviour (Blundell *et al* , 2009).

1.6.2 Satiation and Satiety

Satiation and satiety are part of the body's appetite control system and are involved in limiting energy intake when an individual consumes food (Benelam, 2009). Satiation is the process that causes an individual to terminate the consumption of food/meal; it therefore incorporates all of those events that operate during the meal itself. Satiation appears to be a very basic animal function that even rats with only a hindbrain exhibit (Ritter 2004).

In contrast, satiety is the feeling of fullness that persists after eating, suppressing further consumption. Both are controlled by a 'cascade' (Blundell, 1995) of differing factors that start once a food has been consumed, and continues as it enters the gastrointestinal tract and is digested and absorbed (Benelam, 2009). In response to sensory and cognitive perceptions of the food eaten, signals about the energy spark areas of the brain involved with regulation of energy intake. Satiation is then stimulated. Once the intestines have absorbed the nutrients, signals reach the brain to induce satiety.

Both satiation and satiety are important in determining energy intake. These include rate of intake and total intake, a better understanding of the processes of satiation and satiety, and how they can be influenced and manipulated. Both satiation and satiety can vary in duration and intensity. Satiation can be particularly well measured within the terms of the 'microstructure of eating behaviour' as it is influenced by a number of aspects of food that can be measured in one sitting.

(Blundell *et al* , 2009). These include portion size, energy density of food, taste, texture, palatability and previous exposure. Measuring satiety incorporates more macro structural attributes such as macronutrient composition, viscosity, resistant starch and presence and type of fibre (Blundell *et al* , 2009). Whilst satiation and satiety are intrinsically linked to one another- for example if satiation is modulated by food properties that lead to a change in meal size, then the food in that meal will modulate satiety in the subsequent post meal period-it is important to recognize that they have different experimental procedures.

The satiating effects of foods, such as ice cream, can be measured by allowing participants to consume them *ad libitum* and monitor how much is eaten before satiation is reached (Benelam, 2009). The *ad libitum* consumption of food varies widely, dependent on the food. Weenen *et al* (2005) found that participants ate on average 80g of savoury biscuits, but that they ate almost 5 times as much of pears in syrup. Often measured in a lab environment, this allows for control of foods offered and manipulation of the palatability of the food (Yeomans, 2000). Hetherington (1995) found that 'fullness' and 'boredom with taste' are two reasons for the termination of eating. However, this often depends on what food had been consumed, as the consumption of a single food rather than a meal, is more likely to result in termination due to 'boredom of taste'. Measuring satiety can be achieved by allowing participants to record feelings of hunger or satiety and by measuring food intake directly (Benalam, 2009).

1.6.3 Eating rate

The rate of eating is generally considered to be a sign of appetite and is defined as the amount of food eaten time period usually measured in grams per minute (Elfhag *et al* , 2003). This eating rate is indicative of satiation and not satiety. Eating rate duration could be a vital characteristic of eating behaviour that predisposes an individual to eat excessively. Eating at a faster rate may allow the individual to consume more before the physiological satiation signals can terminate eating. This is has often been suggested to be 20minutes after the meal has started (Spitzer *et al* , 1981). However, Yeoman's *et al* (1997) argued that there is little scientific proof for such a delay.

In experimental situations, favoured meals or foods generate larger, longer meals, with an accelerated rate of eating (Westerterp-Platenga *et al* , 1991). Hill & McCutcheon (1975) suggested that a more rapid eating rate could be associated with the increase in obesity because food intake might be occurring at a rate, which outpaces the normal development of satiation and satiety. However, behaviour in such situations may clearly be dominated by, underlying factors such as state of hunger, eating restraint and palatability.

An indication of the existence of the 'eating curve', the rate at which individuals decelerate consumption during the meal, has been proven to be stable within individuals (Westerterp-Plantenga, 2000). Meyer & Pudel (1972) refer to the eating curve as the 'biological satiation curve' as satiation usually slows down the eating rate in the second part of the meal. Some obese patients find they have an inability to feel satiation, and these participants show an accelerated eating curve in the second part of the meal.

1.6.4 Laboratory vs. Free-living

As has already been mentioned, it is necessary to accurately measure eating behaviour under a variety of conditions and in different environments. The laboratory is one such environment that allows for eating behaviour measurements to be taken under a controlled atmosphere. The purpose of studying eating behaviour in a lab is not to replicate exactly the outside world, with its many variables and distractions, but to gather data through controlled procedures free from social chaos.

The main distinction between the 'free living' and laboratory methods of gathering data is between accuracy and precision (lab based method) and natural living (free living). Eating under free conditions, whilst being considered natural, is not accurate enough, with individuals being asked to self report intake, and often underreporting energy intake (Black *et al* , 1993) and eating in a laboratory, whilst not been seen as natural, allows for precise data to be collected.

1.6.5 Self-reporting measures

The visual analogue scale (VAS) is an important tool when conducting research into eating behaviour and appetite (See chapter 2 appendix for VAS example). Being a method for measuring subjective appetite, it provides insights into eating behaviour that may not be ascertained by voluntary food intake data alone (Blundell *et al* , 2009). Whilst being used in other areas of psychology, such as pain research, VAS has been accepted as a usual method for measuring subjective appetite. The self-reporting style of the VAS being used in appetite research was first use by Silverstone & Stunkard (1968) whilst Rogers & Blundell (1979) developed a version of VAS questions that are still used today.

Typically a 10cm horizontal line, unmarked apart from two extreme anchors at either end by a question associated with a particular state, it is often administered using a pen and paper. VAS are relatively easy to use and process and have been found to be reproducible and valid on a short- term basis, in that the satiety/hunger ratings correlate with energy intake (Flint *et al* . 2000). However, there are concerns that this association with food intake is modest and that caution should be taken in interpreting the results of studies by using VAS, especially if this is the only measure of appetite used (Mattes *et al* . 2005). Experimental studies, such as that of Stubbs *et al* (2000) have shown that the VAS method of assessing subjective appetite sensations is sensitive to manipulations and interference. Studies such as Delargy *et al* , (1996) have also demonstrated the high reproducibility of VAS, whilst a series of reviews have been dedicated to looking at the validity and reliability of VAS (Reid *et al* , 1999).

1.6.6 Measuring intake

Visually coded eating behaviour has been used to measure eating rate (Rogers & Blundell, 1979) whilst others have developed automated ways of assessing intake, such as the Universal Eating Machine (UEM) Guss & Kissileff, 2000). These UEMs generate cumulative intake curves from which within meal changes in eating rate can be identified (Halford *et al* , 2003). Standard mechanized approaches measure food intake via the use of a hidden balance placed underneath the participants plate or bowl, which is linked to a computer to allow continuous recording of the intake of the food. Further development by Yeomans (1996) has enabled the UEM to automatically solicit subjective ratings (much like a computerized VAS) of appetite from participants during regular intervals during the meal. However, the choices of foods that can be measured in a UEM are limited to liquids or semi solid foods such as pasta dishes, soups and yoghurts (Hill *et al*, 1995).

Various data sets have shown that the UEM curves are influenced by gender and food deprivation, as well as the palatability of meals, demonstrating that they are valid representations of the changes in eating behaviour that can occur during meals (Westerterp-Plantenga, 2000). Yeomans (2000) found that manipulating hunger and palatability and measuring these changes with a within meal appetite rating may be useful. Modern UEMs provide good test retest reliability for within individual UEM curves and many authors have commented on the consistency and stability of cumulative intake curves (Hubel *et al* , 2006; Jordan *et al* , 1996)

1.6.7 Effect of palatability and portion size on eating rate

Palatability has been difficult to define in recent years, as it is not an inherent characteristic of food (Yeomans, 1998). It can refer to the pleasurable experience when consuming food (Benalam, 2003) or the effect on immediate ingestion (Booth, 1990). It is generally measured using rating scales. Yeomans (1998) found that by increasing the palatability if food by adding fat, not only increase appetite, but also increase eating rate and meal size.

Palatability had a strong effect on *ad libitum* food intake, both in free-living experiments (De Graff *et al* , 2005) and controlled lab based experiments (De Graff, 1999). Texture is also an important sensory quality that influences satiation, as individuals tend to consume more *ad libitum* liquid based foods, than solid. This could relate to the rate of eating, which is of course higher with liquids (Zijlstra *et al* , 2008). Berridge & Robinson (2003) stated that food was a natural reward consisting of three components; a hedonic component, a motivational competent and a learned component. The sensory characteristics that contribute towards palatability affect both food choice and intake. Simply by altering the flavour of a food increases the amount consumed (Yeomans *et al,* 1997). Drewnowski (1998) found that there is a direct correlation between palatability and energy density of food, with energy dense foods lending themselves to be more palatable. However, this is not a fixed relationship. Manipulating and reformulating foods can alter the association between energy density and palatability altered through taste and texture. Yeomans *et al* (1997) coined the phrase 'the appetiser effect' in his oregano palatability study. Comparing a bland (no oregano) and a palatable (containing oregano) plate of pasta, he found that hunger increased in the first stage of eating the palatable dish and then declined, whilst in comparison, the bland dish showed consumption to decline throughout all the stages of the meal. He also found that participants ate the palatable plate of pasta at a faster rate that the bland plate.

With portion size, it is generally considered that a greater portion size increases energy intake (Benelam, 2003). Ello-Matin *et al* (2005) found that when participants were presented with larger portions, they ate more. Large portion sizes may override the internal homeostatic mechanisms that regulate satiety and satiation. This may be due to decreasing awareness of food consumption, or the distortion of visual cues (Rolls *et al* , 2007). Consumers also find self-regulation of large portions difficult at the moment of consumption (Willemijn, 2009). The effects of large portion sizes on energy intake may also be attributable to a rapid eating rate (Fisher *et al* , 2003). Rapid eating rate may confuse and distort the physiological signals involved in meal termination (Kral *et al* , 2001). This measuring is innately difficult and requires careful study and interpretation of data.

1.6.8 Confounding variables in eating behaviour research

When researching eating behaviour, it is important to consider any potential confounding variables that may impact on any results. These variables can often be categorized into behavioural variables and psychological variables. Dietary restraint, prior knowledge or beliefs about the test foods and physical activity are all behavioural variables which should be considered before any work into eating behaviour takes place. Dietary restraint refers to the restriction of food intake, or the elimination of certain food from the diet, in order to maintain or lose bodyweight (Benelam, 2009). This type of behaviour could be particularly damaging to results (unless of course, you are specifically seeking out patricians who restrict their diet) and experimenters will often use a pre screening dieting questionnaire to assess participant's possible dietary restraints. Regarding prior knowledge about the test foods, Livingstone *et al* (2000) found that if several visits to the laboratory are needed to gather results, participants will become accustomed to the conditions and what is expected of them, which may influence their response. With regards ice cream, with it being such a popular food, many people will have come in contact with it. It also is not a food that people tend to eat as a meal, rather a snack, or desert type food.

The main aims and objectives were to gain an understanding of how product formulation affects consumer preference and if this knowledge could possibly be used for either product reformulation or promotion. Also, to try and understand the limits of human sensitivity regarding absolute structure of a product.

CHAPTER 2: QUESTIONNAIRE AND TASTE TESTS

The decision to take a more in depth look at current commercial ice creams was taken for a number of reasons. These included practical and regulatory problems resulting in a difficulty in producing and replicating large quantities of freshly prepared ice cream due to lack of food grade laboratory equipment and time constraints. It was important that any ice creams used for this research was able to be fed to participants for the sensory/satiation areas of interest. Further investigation into commercially available ice creams was conducted through questionnaires and taste tests. From these results, a more detailed approach to the eating behaviour of these ice creams could be gained. Following this, formulation based investigations were enacted in order to confirm or deny/back up/ reinforce the eating behaviour results.

Firstly, an ice cream questionnaire study was undertaken. Following this an ice cream palatability taste test was conducted.

2.1 Ice cream questionnaire study

The objective of this study was to gain knowledge into the ice cream eating and purchasing habits of young adults (between the ages of 18-22) in order to design an ice cream taste test experiment, which was to be carried out which was to be carried out following the results gathered.

2.1.1 Methodology

2.1.1.1 Participants

100 participants took part in the ice cream questionnaire study, however; only 95 questionnaires could be used for analysis. From these 95, 62 males and 33 females. 73 participants were undergraduate students, and 21 were postgraduate students, and 1 member of staff. All were based in the Chemical Engineering Department of Birmingham University.

Participants were chosen using a purposive sampling method. Galloway (1997) describes purposive sampling methods as “A purposive sample is one which is selected by the researcher subjectively. The researcher attempts to obtain sample that appears to him/her to be representative of the population and will usually try to ensure that a range from one extreme to the other is included “. The primary reason for purposively selecting these participants was that the answers that they gave were to be used in a following taste test experiment, and participants for that experiment could be chosen from the answers they gave in this experiment. A subsequent reason in selecting these participants to take part in answering the questionnaire as there were a range of ages within the group. Typically, children between the ages of 2-12 years old drive the ice cream market, with households with children leading consumer intake of ice cream at 34%. This is compared to 20% of households consuming where there were no children. (Barrette, 2004).

Therefore, by selecting participants between the ages of 17-28 results can be gained into the ice cream eating and purchasing habits this particular age range.

Subsequent to verbal consent being obtained from the participants, the questionnaires were handed out.

2.1.1.2 Questionnaire Design

The questionnaire was designed to be simple and quick to answer. Participants were asked to write down their name, age (in years and months) –this was to gain a more accurate account of age range- their sex, which was a fixed-choice question, and their university email address.

The questionnaire then consisted of 13 questions, which were a mix of open ended (i.e. Question 10) fixed choice (i.e. Question 1) and a series of balanced scale questions (i.e. Question 3). Please see Chapter 2 appendix for questionnaire.

2.1.1.3 Procedure

77 undergraduate chemical engineering students were approached at the end of a lecture in a chemical engineering lecture hall. The study and its aims were clearly explained to them, and before being given a questionnaire, verbal consent was gained from each participant. The participants then proceeded to answer the questionnaire, and when they had finished, were told to pass it to the end of the row, where it would collect. They were then thanked, and debriefed.

21 postgraduate students and 1 member of staff were then approached on a random basis. The study and its aims were explained once again, as well as verbal consent being gained before questionnaires were answered. When they had finished, they were thanked and debrief. The postgraduate students were also

told that they may be called upon to take part in ice cream taste test that the results of the questionnaire study was aiding to design. However, it was clearly explained that participation in this was not compulsory.

2.1.1.4 Ethics

All British Psychological Society (2005) guidelines were adhered to, and informed and verbal consent was gained from each participant. All participants were verbally informed, and it was explained that participation was not compulsory. All participants were told that they had the right to withdraw from the study at any time, without consequence. Participants were also debriefed after the study. All were thanked for their participation in the study. All information gathered was kept confidential and anonymity was observed.

2.1.2 Results

100 questionnaires were given out to individuals in the chemical engineering Department of Birmingham University. From these 100 given out, 95 could be used for analysis. The purpose of this questionnaire was to gauge a better understanding of consumers eating and purchasing habits of ice cream. The results gained were to be used to shape future experimental design into the palatability of ice cream.

2.1.2.1 Sex

From the results, we could see that 62 males and 33 females took part in answering the questionnaire.

2.1.2.2 Age

Ages ranged from 17 years 8 months to 43 years 1 month. The average age was 19 years 7 months, and that the most frequent age were 18 years 5 months.

2.1.2.3 Smoke/diet/health

From the table below, it is clear to see that eight of the participants smoke, four have been on a strict diet in the past six months and seven participants are potential health risks due to medical conditions/allergies. These participants will be filtered out and not be included in future experiments.

Table 2.1: Smoke/diet/health

Smoke				
	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	8	8.4	8.4	8.4
No	87	91.6	91.6	100.0
Total	95	100.0	100.0	
Diet				
	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	4	4.2	4.2	4.2
No	91	95.8	95.8	100.0
Total	95	100.0	100.0	
Health risk				
	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	7	7.4	7.4	7.4
No	88	92.6	92.6	100.0
Total	95	100.0	100.0	

2.1.2.4 Do you eat ice cream?

From the table below, it can be concluded that all 95 participants answered that they do eat ice cream.

Table 2.2: Do you eat ice cream?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	95	100.0	100.0	100.0

2.1.2.5 How often do you eat ice cream?

From the table below, it can be concluded that 52 of the participants eat ice cream at least once a month, 38 at least once a week, and 5 once every 6 months. No participants answered once a year or never.

Table 2.3: Frequency of eating ice cream

Frequency of eating ice cream				
	Frequency	Percent	Valid Percent	Cumulative Percent
Once a week	38	40.0	40.0	40.0
Once a month	52	54.7	54.7	94.7
Once every 6 months	5	5.3	5.3	100.0
Total	95	100.0	100.0	

2.1.2.6 Where do you purchase ice cream?

From the results below, it can be concluded that the most popular place to purchase ice cream from is the supermarket, as 21 participants answered that they always purchase ice cream from here, and 41 participants answered that they often purchase ice cream from here. The least popular place to purchase ice cream from is the cinema (57 answered never) followed by delicatessen (52 answered never). From these results, it can be concluded that the best place for ice cream purchase for future experiments would be the supermarket, rather than any other area.

Table 2.4: Where do you purchase ice cream?

Where do you purchase ice cream?				
Place	Frequency			
	Never	Sometimes	Often	Always
Supermarket	2	31	41	21
Van	22	59	13	1
Cinema	57	30	8	0
Corner shop	40	39	14	2
Fast food	34	42	18	1
Deli	52	31	11	1

2.1.2.7 Brands

From the results below, it can be clearly seen that there is a difference between each of the brands. Ben & Jerry's is clearly the most popular, as 12 participants claimed that they always buy it, with Haagen Daz second with nine participants claiming they always buy it. These two brands also score highly in the often and sometimes categories. Green & Blacks was the least popular, with 72 participants reporting that they never purchase Green & Blacks.

These results are useful for future experiments as can indicate the possible brands to use, particularly if the experimenter wishes to match or avoid brands for certain experiments.

Table 2.5: Brand purchase

Brand purchase				
Brand	Frequency			
	Never	Sometimes	Often	Always
Ben and Jerry's	16	39	28	12
Cart Dor	27	37	25	6
Haagen Daz	26	46	14	9
Green & Blacks	74	18	2	1
Supermarket own brand	32	33	27	3
Baskin Robbins	66	23	5	1
McDonalds	26	40	22	7
Other	72	12	7	4

2.1.2.8 Ice cream texture

From the table below, it is clear to see that 40 of the participants prefer hard ice cream, followed by 32 that had no preference.

Table 2.6: Ice cream texture preference

Ice cream texture					
		Frequency	Percent	Valid Percent	Cumulative Percent
	Soft	23	24.2	24.2	24.2
	Hard	40	42.1	42.1	66.3
	No preference	32	33.7	33.7	100.0
	Total	95	100.0	100.0	

2.1.2.9 Types of ice cream

From the results below, it is clear that most common type of ice cream purchased is a tub of ice cream, as 17 participants claimed that they always buy ice cream this way. The least popular way was both cup and stick. This indicates that when designing an experiment with different types of ice cream, the most popular choice to use would be ice cream from a tub/container.

Table 2.7: Types of ice cream consumed

Types of ice cream				
Type	Frequency			
	Never	Sometimes	Often	Always
Stick	35	43	14	3
Cone	5	52	29	9
Cup	35	38	15	7
Tub	8	30	40	17

2.1.2.10 How do you eat ice cream?

From the results below, understanding the manner in which participants consume ice cream can be drawn. This is important to know for future experiments as it can aid the design of how ice cream may be presented to the participants, whether that be a familiar way, or an unfamiliar way. The results indicate that the most popular way to eat ice cream is scooped from a tub into a bowl. This is clear as 17 participants answered that they always eat ice cream this way, and 47 and 31 indicated that they often and sometimes eat it in this manner. Also, no one participant answered that they never eat ice cream this way. The least popular way to consume ice cream is clearly with a cold pudding, with 43 participants answering that they never eat ice cream in this way. It was also reasonable common to eat ice cream as a stand-alone pudding when compared to eating it with a pudding.

Table 2.8: Method in which ice cream is consumed

How ice cream is eaten?				
Manner in which it is eaten	Frequency			
	Never	Sometimes	Often	Always
Bowl	0	31	47	17
Cone	32	42	21	0
Hot pudding	28	43	22	2
Cold pudding	43	44	8	0
On its own	21	39	32	3

2.1.2.11 When do you eat ice cream?

This was a vital question that needed to be answered for the design of future experiments. This is because if ice cream is offered to participants at the wrong time of day, this could impact heavily on results. From these results in the below table, it is clear to see that 43 of the participants never eat ice cream after lunch, and 36 never eat it as a snack. The highest number of participants ate ice cream sometimes after dinner. These answers need to be considered carefully for future experimental design.

Table 2.9: When ice cream is consumed

When is ice cream eaten?				
When	Frequency			
	Never	Sometimes	Often	Always
Snack	36	32	21	6
After lunch	43	37	12	3
After dinner	7	51	30	7

2.1.2.12 Factors when purchasing ice cream

This question sought to discover what factors participants take into consideration when purchasing ice cream, and how important they deem these factors to be. From the table below, it can be concluded that taste is the most important factor as 73 participants answered this is a very important factor, followed by brand (56), followed by 33 participants deeming mouth feel as the next very important factor. The least important factors that gained the most answers were the calorie content of the ice cream and whether or not the ice cream was soft scoop.

Table 2.10: Factors influencing ice cream purchase

Factors when purchasing ice cream				
Factor	Frequency			
	Very important	Important	Not important	Not at all important
Price	23	53	17	2
Brand	18	56	17	4
Packaging	5	38	42	10
Appearance	17	61	11	6
Mouth feel	34	47	10	4
Taste	73	20	1	1
Calorie content	5	10	44	36
Soft scoop	4	21	59	11

2.1.2.13 Brand association

From the tables below it can be seen that 56 participants associated high quality ice cream with certain brands, whilst 39 did not. 56 participants also scored branding as important in the previous table. In the second table, it can be seen which brands the participants associated with high quality ice cream. This can aid future experimental design by knowing which ice creams participants deem high quality and decided whether to include or exclude in experiments.

Table 2.11: Ice cream brand association

Brand association					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	56	58.9	58.9	58.9
	No	39	41.1	41.1	100.0
	Total	95	100.0	100.0	

Table 2.12: Ice cream brand association

Brands				
	Frequency	Percent	Valid Percent	Cumulative Percent
None	38	40.0	40.0	40.0
Haagen Daz	17	17.9	17.9	57.9
Ben and Jerry’s	15	15.8	15.8	73.7
Walls/Cart D'or	17	17.9	17.9	91.6
Mackie’s	1	1.1	1.1	92.6
Joes	1	1.1	1.1	93.7
Green & Blacks	3	3.2	3.2	96.8
Miko	1	1.1	1.1	97.9
Baskin Robbins	1	1.1	1.1	98.9
Kelly’s	1	1.1	1.1	100.0
Total	95	100.0	100.0	

2.1.2.14 Qualities

In the table below, it can be seen which qualities the participants thought were important in a good quality vanilla ice cream. This was an open-ended question, and so answers were categorised into the most popular terms used. It is clear to see that taste is the most important quality, as 52 of the participants gave this answer. The next most popular answer was texture, which covered answers such as hard/soft/creamy/smooth.

Table 2.13: Ice cream quality

	Frequency
Taste	52
Mouth feel	6
Appearance	1
Texture	17
Flavour	6
Vanilla taste	10
Sweetness	1
None	1
Price	1
Total	95

2.1.3 Discussion

The results from this study are both interesting and important to future research into the eating and purchasing habits of young adult consumers of ice cream. From the results gained from this questionnaire study, a suitable ice cream taste test can be carried out. The results from both this study and the ice cream taste test study were used to finalize an experimental design and obtain data with which to better understand the palatability of vanilla ice cream.

Results are in keeping with that of Rea (2004) who found that branded ice creams such as Ben & Jerry’s are most popular (15.8%) and that branded ice creams are in fact associated with a higher and better quality of ice cream (58.9%). As children are the main consumers of ice cream, it would be beneficial if more research into the eating habits of adults were carried out, as future trends, such as low fat and low sugar ice creams appear on the market. The consumer is increasingly conscious about what they eat, both in terms of evolved health, i.e. natural and functional foods, and in terms of ethics and provenance. Innovations from the ice cream industry have improved greatly through extensions of the Green & Black’s brand and more ethical products from Ben & Jerry’s (Food and Drink International, 2006).

With regards moulding an experimental design for a taste test into the palatability of ice cream, these results have been incredibly useful. Results indicate that taste, texture and vanilla taste are all vital to a well-balanced high quality ice cream. Whilst appearance did not score particularly highly on the ‘important qualities in a vanilla ice cream question’, it may be wise to avoid ice creams that contain visible vanilla seeds in the ice cream. This is because it is often associated with a higher quality of ice cream, and if wanting to compare low and high quality ice creams in the taste test experiment, the vanilla seeds may act as a visual cue. The results also show that the most popular place to purchase ice cream from is the supermarket, so ice creams that will be used in the taste test should be bought from the supermarket.

2.2 Ice cream palatability taste test and portion size test

The objective of this study was to discover which ice creams were more palatable to participants from two sets of ice cream; Basic ice creams and premium ice creams. These ice creams were chosen based on price and ingredients i.e. an ice cream that used vegetable oil, as the fat was considered basic, whilst one that included cream as its fat component was considered premium. A subsequent objective was to better understand portion sizes by asking participants to choose their optimal portion size of ice cream from photographs. Below are the hypotheses to be tested. H0 is considered to be the null hypothesis.

H1: It is predicted that there will be a significant difference in the enjoyment of taste scores between the two basic ice creams (two tailed)

H0: There will be no difference between the enjoyments of taste scores of the two basic ice creams

H2: It is predicted that there will be a significant difference in the enjoyment of taste scores between the two premium ice creams (two tailed)

H0: There will be no difference between the enjoyment of taste scores of the two premium ice creams

H3: It is predicted that there will be a significant difference between the enjoyment of taste scores of the highest scoring premium ice cream and highest scoring basic ice cream (two tailed)

H0: There will be no difference between the enjoyment of taste scores of the highest scoring premium ice cream and the highest scoring basic ice cream

H4: The largest portion size (200g) will be the most popular chosen portion size (one tailed)

H4: The largest portion size (200g) will not be the most popular chosen portion size.

2.2.1 Methodology

2.2.1.1 Participants

16 participants took part in the ice cream palatability taste test study. From these 10 were male and 6 were female. All were postgraduate students based in the chemical engineering Department of Birmingham University. Participants were chosen using a simple random sampling technique. Easton & McColl (1997) define this sampling technique as 'basic sampling technique where we select a group of subjects (a sample) for study from a larger group (a population). Each individual is chosen entirely by chance and each member of the population has an equal chance of being included in the sample'. An advantage of this type of sampling is that it should be free from bias as it is totally random.

30 participants took part in the portion size exercise. 16 of these were the same participants that took part in the ice cream taste test, and the other 14 participants

were chosen at random. Some of these participants took part in the questionnaire study, whilst some others did not.

2.2.1.2 Design

A repeated measures design was employed for the ice cream palatability taste test. A repeated measures (or paired samples) design is defined as ‘ a technique used when you test the same people on more than one occasion’ (Pallent, 2007). Two basic ice creams were compared, as were two premium ice creams. The dependent variables in this study were the VAS scores given for the ice creams, whilst the independent variable was the type of ice cream.

For the portion size exercise, the dependent variable was the portion size chosen (A, B, C, D), whilst the independent variable was the photographs of the portion size that the participants were shown.

2.2.1.3 Materials

For the ice cream taste test, materials included the two basic ice creams and two premium ice creams. The basic ice creams were Sainsbury’s basic vanilla ice cream, and Waitrose essentials vanilla ice creams. These were chosen as the basic ice creams due to their fat content type-vegetable fat rather than dairy fat and their price. The premium ice creams were Duchy’s original organic vanilla ice cream, and Mackie’s Scottish ice cream. These were chosen as the premium ice creams because of their total fat content, and fat content type- sourced from diary fat rather than vegetable fat. Their cost of purchase was also an indication of their premium status. These ice creams were also specially chosen from results gained in the ice cream questionnaire study. It had been decided that the premium ice creams chosen should not contain any visible vanilla seeds, as this could have been used by the participants, consciously or unconsciously, as a visual cue. This is the reason Duchy's and Mackie's were chosen, as these were two of the only premium ice creams found containing no visible vanilla seeds. The ice creams were also all bought from supermarkets, as this was the most popular place participants in the questionnaire study bought ice cream from, and also was the most convenient for use in the experiments as they were easily attainable.

Table 2.14: Ice cream composition

	Mackie's (100g/200g)	Sainsbury's basics (100g/200g)	Duchy's original (100g/200g)	Waitrose essential (100g/200g)
Price (p)	29.7p/59.4p	4.5p/9p	42.9p/85.8p	11.5p/23p
Energy kcal	204kcal/408kcal	134kcal/268kcal	149kcal/298kcal	64kcal/128kcal
Energy kJ	855kJ/1710kJ	565kJ/1130kJ	623kJ/1246kJ	269kJ/538kj
Protein	3.6g/7.2g	2.5g/5g	2.8g/5.6g	1.3g/2.6g
Carbohydrate	23.2g.46.4g	19.7g/39.4g	12.5g/25g	8.2g/16.4g
Of which sugars	N/A	17.5g/35g	12.5g/25g	7.9g/15.8g
Fat	10.8g/21.6g	5.1g/10.2g	9.8g/19.6g	2.9g/5.8g
Of which saturates	N/A	3.2g/6.4g	6.0g/12.g	2.5g/5g

Other materials included plastic spoons, plastic cups with bottled water and crackers (to palate cleanse between each sample), ice cream samples which were presented in small shot glasses labeled A and B, pens and visual analogue scale questionnaires.

The visual analogue scale questionnaire consisted of 3 questions, how enjoyable was the taste of this ice cream, how visually pleasing was the ice cream, and would you purchase this ice cream to eat at home. This study was mainly interested in the scores of the first question (how enjoyable was the taste of this ice cream?) but it was felt that other questions should be added. (See chapter 2 appendix for examples of these VAS questions)

For the portion size exercise, materials included 4 photographs of differing ice cream portion sizes (A=150g, B=50g, C=200g, D=100g) and a short fixed question asking participants to look at the photographs-which were only labeled A-D, the grams were not given- and circle the appropriate answer.

Figure 2.1: Photographs of ice cream portion size

2.2.1.4 Procedure

16 postgraduate students were approached in the chemical engineering Department of Birmingham University. The study and its aims were clearly explained to them; however, they were not told that they would be eating basic and premium ice creams. Verbal consent was gained from each participant before the taste test began. Participants were invited to a room, and asked to sit down, pour themselves a cup of water, and eat a small water cracker. They were then asked to read the top page of the VAS scale questionnaire, which contained an example of how to fill in a VAS. Whilst the participants were doing this, the experimenter went behind a screen to obtain the first set of ice cream samples, -Taste test 1-which were the basic ice creams. Sample A was the Sainsbury's basics vanilla ice cream, and Sample B was the Waitrose essential vanilla ice cream, but the participants were not told this. Sample A was brought out first, and participants were asked to turn the VAS questionnaire over to the first question, eat some of sample A and then answer the questions. After they has completed the questions for sample A, they were asked to palette cleanse with the water and crackers, whilst Sample B was prepared. Sample B was then brought out to the participants, and the same procedure for sample A was repeated. Following the completion of these questions, they were asked to turn the VAS questionnaire over to taste test 2, participants were once again asked to palette cleanse. The premium ice cream samples were then prepared. Sample A was the Mackie ice cream, and sample B was the Duchy's vanilla ice cream- however, once again, the participants didn't know this. The same procedure as taste test 1 was then

repeated. After participants had completed the VAS questionnaire, they were asked to turn to the last page of the questionnaire, which contained the portion size exercise. They were asked to look at four photographs of differing size portions of ice cream in bowls. They were not told the weight of the differing portions, but just asked a fixed question as to which portion size they would prefer. All participants were then thanked and debriefed.

The remaining 14 participants that took part in the portion size exercise were then selected at random, and once again asked to look at the photographs of ice cream portions, and asked to select which portion they would prefer. These participants were then thanked and debriefed.

2.2.2 Results

The experimental hypotheses being tested were:

H1: It is predicted that there will be a significant difference in the taste scores between the two basic ice creams (two tailed)

H2: It is predicted that there will be a significant difference in the taste scores between the two premium ice creams (two tailed)

H3: It is predicted that there will be a significant difference between the taste scores of the highest scoring premium ice cream and highest scoring basic ice cream (two tailed)

H4: The largest portion size (200g) will be the most frequently chosen portion size (one tailed)

In order to assess whether there was a significant difference in the taste scores between the two basic ice creams, a repeated measures comparisons of means t test was carried out. This was in order to analyze the data collected from the VAS questionnaire complete for taste test 1.

The purpose for choosing a repeated measures test was due to the data collected being at interval level, and a repeated measures comparisons of means test looks for a difference between two related groups (Banister, 1997). The parametric assumptions were met; data was at interval level, the data was normally distributed and the repeated measures comparison of means test makes no assumptions of homogeneity of variance.

2.2.2.1 Taste test 1-Basic ice creams

A repeated measures comparison of means t test was conducted to evaluate the enjoyment of taste VAS scores of two basic ice cream samples.

Table 2.15 shows the descriptive statistics (Means and SD) for the VAS scores for enjoyment of taste for taste test 1.

Table 2.15: Descriptive statistics for taste test 1

Descriptive statistics (Means and SD) for the enjoyment of taste VAS scores for taste test 1		
	Mean VAS score	Standard deviation
Sainsbury's Basic Vanilla Ice cream	58.3	21.6
Waitrose essentials vanilla ice cream	45.3	20.1

Table 2.15 shows that the mean VAS scores for enjoyment of taste for Sainsbury's basic vanilla ice cream (mean=58.3, SD=21.6) compared to Waitrose essential vanilla ice cream (mean=45.3, SD=20.1). This higher score denotes that the Sainsbury's ice cream had a more enjoyable taste that than that of the Waitrose ice cream. However, this difference in scores was not proven to be significant.

T=1.791, DF=15, p=0.094

2.2.2.2 Taste test 2- Premium ice creams

A repeated measures comparison of means t test was carried out to evaluate the enjoyment of taste VAS scores of two premium ice cream samples.

Table 2.16 shows the descriptive statistic (Means and SD) for the enjoyment of taste VAS scores for taste test 2.

Table 2.16: Descriptive statistics for taste test 2

Means and descriptive statistics for the enjoyment of taste VAS scores for taste test 2.		
	Mean VAS score	Standard deviation
Duchy's vanilla ice cream	61.6	14.1
Mackie's ice cream	72.1	19.1

Table 2.16 shows the means VAS scores for the enjoyment of taste for the Duchy's vanilla ice cream (mean=61.6,SD=14.1) compared to Mackie's ice cream (Mean=72.1, SD=19.1). The higher score from the Mackie's ice cream indicates that the Mackie's had a more enjoyable taste. However, this difference in scores was not proven to be significant.

T=1.839,DF=15,p=0.086

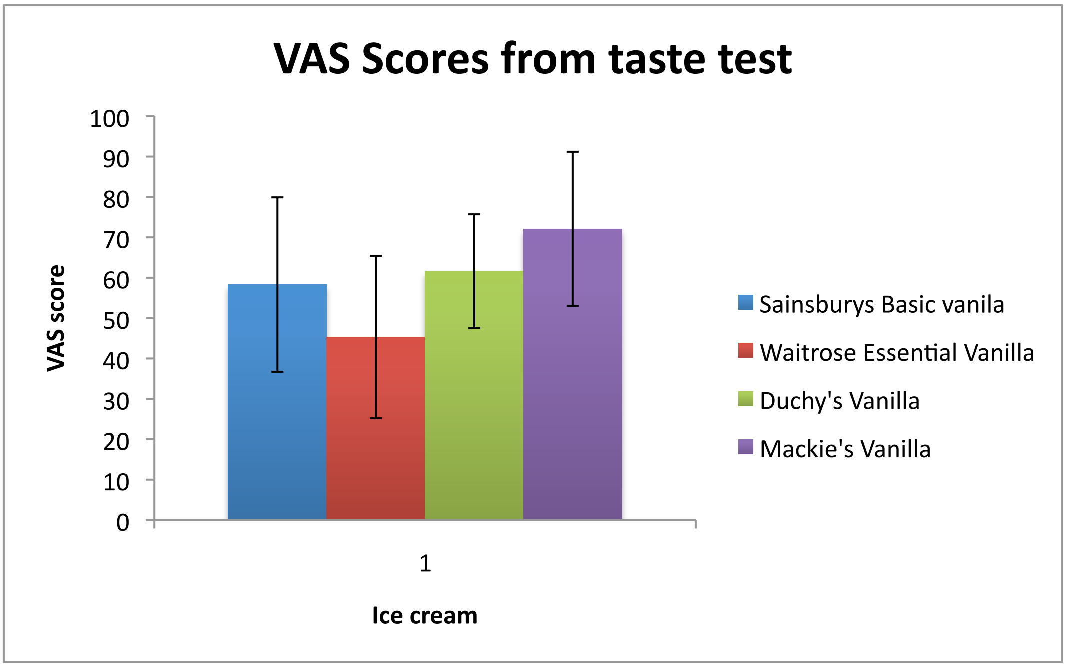


Figure 2.2: Visual analogue scores for taste tests

A further repeated measures comparison of means t test was then carried out to evaluate whether there was a significant difference in the enjoyment of taste VAS score between the highest scoring premium ice cream (Mackie's, mean=72.1) and the highest scoring basic ice cream (Sainsbury's, mean =58.3)

Table 2.17 shows the descriptive statistics (Means and SD) for the enjoyment of taste VAS scores for the highest scoring premium and basic ice cream.

Table 2.17: Descriptive statistics for highest scoring premium and basic ice creams

Means and descriptive statistics for the enjoyment of taste VAS scores for the highest scoring premium and basic ice creams.		
	Mean VAS score	Standard deviation
Sainsbury's basic vanilla ice cream	58.3	21.6
Mackie's ice cream	72.1	19.1

The table above shows that there is an obvious difference in the mean scores between the Sainsbury's and the Mackie's ice creams, and this is shown to be a statistically significant difference.

T=2.474, DF=15, p=0.026

2.2.2.3 Portion size results

The results from the portion size exercise can be seen in Table 2.18

Table 2.18: Portion size exercise

Portion Size exercise		
Portion size (grams) (photograph label)	Frequency	Percentage frequency
150g (A)	8	26.7
50g(B)	1	3.3
200g(C)	11	36.7
100g(D)	10	33.3

From this table of frequencies, it can be concluded that the most frequently chosen portion size was 200g, closely followed by 100g.

2.2.3 Discussion

The experimental hypotheses being tested were:

H1: It is predicted that there will be a significant difference in the taste scores between the two basic ice creams (two tailed)

H2: It is predicted that there will be a significant difference in the taste scores between the two premium ice creams (two tailed)

The results from the ice cream taste study showed that whilst there was a slight difference between these scores, they were not of a significant level. Therefore we cannot reject the null hypothesis.

H3: It is predicted that there will be a significant difference between the taste scores of the highest scoring premium ice cream and highest scoring basic ice cream (two tailed)

H4: The largest portion size (200g) will be the most popular chosen portion size (one tailed)

Both of these hypotheses were proven and therefore the null hypothesis can be rejected.

The results from this study have indicated potential ice creams, both basic and premium that could be used in future research into ice cream palatability. It has also indicated potential portion sizes that could be used. As portion size is so closely related to energy intake and rate of intake, this may be a sensible direction to focus future work.

Results showed that whilst there was not a significant difference between the two basic and two premium ice creams, there was a significant difference between the highest scoring premium and highest scoring basic ice creams. The purpose for comparing these two ice creams was that the lower scoring basic ice cream (Waitrose essential) scored so low that any future experiments that used this ice cream may find that participants dislike its taste so much, that they refuse to eat it, which would skew research results into eating rate for example.

The use of the VAS was of great benefit to this study. Verbal feedback from participants indicated that they found it easy to use and easier to answer than a numbered Likert scale. The taste test panel was representative of the consumer market of interest and that test procedures were kept simple and the number of items compared were small, which were in keeping with Bradley (1955) instructions on a taste panel for consumer testing.

The results from the portion size exercise were interesting and in keeping with previous research. A large proportion of the participants chose the largest portion size (200g), and future research may benefit from examining the link between large portion size and rate of intake as Matin *et al* (2005) found that when participants were presented with larger portions, they ate more. It may also be interesting to examine the idea of Willemijn (2009) who stated that consumers find self-regulation of large portions difficult at the moment of consumption. The examining of the effects of large portion sizes on energy intake on rapid eating rate could also take place. The idea that rapid eating rate may confuse and distort the physiological signals involved in meal termination could also be examined, but the practicalities of measuring of this must be considered carefully.

CHAPTER 3: MATERIAL PROPERTIES AND CHARACTERISATION OF ICE CREAM

Following on from the previous chapters results regarding taste preference and the clear differences in preferences in relation to structural perception, and the future eating behaviour experiments that were due to be carried out with participants, it was felt that a broader knowledge of the crucial principles and fundamentals of basic ice cream emulsions was needed. This was primarily due to the fact that any future eating experiments that were carried out would be done over a prolonged period of time (15minutes+) and it was important to establish time scales of destabilisation for these experiments. There needed to be confidence that the material would be stable for the future time scales needed.

Therefore, the decision was taken to prepare and test some basic ice cream emulsions to in order to gain understanding of material stability.

A model system of four basic oil in water emulsions were prepared. All consisted of the equal amounts of milk protein (2.5% sodium caseinate) but differed in ratios of fat (Vegetable oil) and water (double distilled). The purpose of a model system was to provide boundary limits to the responses of real materials and industry relevant trends in data.

These emulsions were then investigated in relation to influence of shear time on fat particle size with no emulsifier or stabilizer mixture, then influence of emulsifier and stabilizer mixture (e/s) (0.5% and 1%) on fat particle size and effect of homogenization on fat particle size.

Experiments were then carried out which looked at current ice cream available on the market, and dealt with the rate at which the fat in these ice creams melted and the tribology of the ice creams.

3.1 Material and methods

3.1.1 Emulsion preparation

3.1.1.1 No emulsifier or stabiliser

For the first experiment, no emulsifier or stabilizer was added, as the amount of emulsifier and stabilizer and its affect on fat particle size and fat stability was investigated in a following experiment.

Protein was weighed out, as was distilled water and vegetable oil. Protein was then dispersed in the cold distilled water and mixed under stirring using a magnetic stirrer for 10 minutes. This mixture was then finely mixed with the vegetable oil in a glass beaker in a Silverson high shear mixer at 10700Rpm for 1 minute.

This procedure was then repeated for another four basic o/w emulsions of the same compositions as above; however, these were mixed at 10700Rpm in a Silverson high shear mixer for 5 minutes.

The procedure was then repeated for a third time, following the same composition as before, but the emulsions this time were high shear mixed for 10 minutes.

Post high shear mixing, each emulsion was then observed under a light microscope and mastersizer in order to determine the fat droplet size and distribution.

Table 3.1: Basic emulsion no emulsifier/stabiliser mix

Fat (Vegetable oil) (%)	Water (%)	Milk Protein (Sodium Caseinate) (%)
30	67.5	2.5
20	77.5	2.5
10	87.5	2.5
5	92.5	2.5

3.1.1.2 Stabilizer and emulsifier mix

Four o/w emulsions were prepared. They all consisted of the same amount of milk protein, 2.5% sodium caseinate and 0.5% of a commercial blend of polysaccharide stabilizers (Locus bean gum, Guar gum) and mono- and diglycerides (Dairylux 476), but differed in ratios of fat and water.

Table 3.2: Basic emulsion (0.5% emulsifier/stabiliser mix)

Fat (Vegetable oil) (%)	Water (%)	Protein (Sodium Caseinate) (%)	E/S (emulisfier/stablizer) mix (%)
30	67	2.5	0.5
20	77	2.5	0.5
10	87	2.5	0.5
5	92	2.5	0.5

The dry ingredients were weighed, as was the distilled water and vegetable oil. Protein was then dispersed in the distilled water and mixed under stirring for 10 minutes. The vegetable oil was then heated to 50°c and the blend of emulsifier and stabilizer was added and mixed under stirring until it had dissolved (around 15 minutes). Both the hot oil and the distilled water and protein solution were then finely mixed in a Silverson high shear mixer at 10700Rpm for 10 minutes.

This was then repeated for four more emulsions; however each contained 1% of the commercial blend of polysaccharide stabilizers and mono-glycerides

Table 3.3: Basic emulsion (1% emulsifier/stabiliser mix)

Fat (Vegetable oil) (%)	Water (%)	Protein (Sodium Caseinate) (%)	E/S mix (%)
30	66.5	2.5	1
20	76.5	2.5	1
10	86.5	2.5	1
5	92.5	2.5	1

All of these emulsions were then observed in a mastersizer to determine the fat droplet size. After this, the samples were place in a fridge and stored at 2˚c where they were observed for creaming and therefore the stability of the fat particles in the continuous phase of the emulsion. Results from these experiments were then used to decide which fat percentage emulsion should be used for the homogenization experiments.

3.1.1.3 Homogenized samples

Oil in water emulsions were prepared. As results from the e/s mix experiments indicated that those emulsions containing the 1% e/s mix were the most stable and had smaller fat particle size, and the most stable of the emulsions was the 30% fat, it was decided that this should be the emulsion to investigate the effect of homogenization on fat droplet size.

Table 3.4: Homogenised samples

Fat-Vegetable oil (%)	Milk Protein-Sodium Caseinate (%)	Distilled Water (%)	E/S (%)
30	2.5	66.5	1

The dry ingredients were weighed, as was the distilled water and vegetable oil. Protein was then dispersed in the distilled water and mixed under stirring for 10 minutes. The vegetable oil was then heated to 50°c and the blend of emulsifier and stabilizer was added and mixed under stirring until it had dissolved (around 15 minutes). Both the hot oil and the distilled water and protein solution were then finely mixed in a Silverson high shear mixer at 10700Rpm for 10 minutes. Sample 1 was then passed through a high-pressure homogenizer at 70 bar. Sample 2 was passed through the homogenizer twice, and sample 3 was passed through three times.

Samples were then observed through an electron microscope and mastersizer to determine fat droplet size. This was necessary to determine whether the fat droplet size and distribution was altered post homogenization.

Samples were then left in a fridge and observed for creaming to determine whether homogenization had any impact on the creaming and stability of the emulsions.

3.1.1.4 Commercially available ice creams

Two ice creams available on the commercial market were purchased and stored in a chest freezer at -20°c for 3 weeks. They varied in fat type and content and overall quality. These were the lower quality Sainsbury's basics Vanilla ice cream that had been used in the previous taste test preference tests, and Green & Blacks Vanilla ice cream, that had not been used, but was the only higher quality ice cream available at the time of testing. Samples were tested using a tribometer to measure in mouth lubrication.

Table 3.5: Commercially available ice creams

Ice Creams	Fat	Protein	Emulsifiers	Stabilizers
Green & Blacks	Whole Milk and whipping cream (26%)	Skimmed Milk Powder	Whole egg	Guar Gum, Xanthan Gum, Locus Bean Gum
Sainsbury's Basics Vanilla Soft Scoop	Palm oil	Reconstituted Whey	Mono-and diglycerides	Guar Gum and Sodium alginate

3.2 Instrumental measurement methods

3.2.1 Particle size measurement

All the emulsions were analysed for their fat droplet size and distribution and determination of their mean volume diameter. This size parameter was deuced from integrated laser light scattering measurements by using a Mastersizer (Malvern mastersizer). Samples were brought to room temperature and gently stirred before sampling and dilution in distilled water was approx. 1:1000. The presentation factor was selected by measuring the refractive index of dispersed fat relative to water. The mastersizer was then cleaned out with Deacon and distilled water between each sample run. Particle size refers to mean particle size throughout the results.

3.2.2 Microscopy

A light microscope (Reichert-Yung light microscope) was used to observe the fat globules and distribution in the emulsions. The emulsions were prepared for the microscopy by stirring the emulsions with a fine pipette and a small amount (approx. 1ml) was then spread on a glass microscope slide. To obtain a flat image, a glass cover slip was placed over the sample prior to observation.

3.2.3 Creaming Profiles

In order to observe the stability of the emulsions, a visual assessment of them was carried out. This was performed by placing the emulsion in a plastic volumetric test tube with a total graduation of 14ml in 1ml steps. The samples were left in a fridge at 2˚c and serum volume was noted for a total time of 24hrs. This was a vital mechanism for testing the primary destabilization mechanism of that fat phase of ice cream over prolonged testing time scales.

3.2.4 Tribology

As discussed in the literature review, tribology is the science of friction and lubrication and whilst most commonly used in the context of metal processing, has been used to correlate in mouth responses to food (Malone *et al* , 2003). Dresselhuis *et al* (2007) demonstrated an inverse relation between fat perception and in mouth friction sensed between the tongue and the palate. Tribology therefore would be a beneficial way of relating the fat perception and content of the bought ice creams and in mouth friction.

A mini traction machine developed by PCS instruments was used. Data were gathered at 37°c to replicate in mouth conditions of melted ice cream. A Stribeck curve formed of variable speeds from 1mm/s to 1000mm/s in ascending order and using a ball on disc method. A precision steel ball was used together with a 46mm diameter silicone disc. Before the sample reached the required temperature, dependent on which experiment was being carried out, the machine was set at an idle speed and the ball applied no load to the sample or the disc. One the temperature was equilibrated the ball applied a load of 2N and the test run began. Each test carried out twice, once with the Green & Blacks sample, and the second with the Sainsbury's basics.

3.3 Results and discussion

3.3.1 Basic emulsions with no e/s mix

Below is a table showing the fat particle size results of the shear time experiments for the basic emulsions containing no e/s mix.

Table 3.6: Particle size (Volume/weight) for basic emulsions no e/s mix

Fat content	Shear time	D [4,3]	D [3,2] µm	d (0.1)	d(0.5)	d(0.9)
5%	1minute	33.2	9.9	6.0	16.6	33.9
	5 minutes	29.2	5.5	2.8	9.1	21.1
	10 minutes	9.1	4.4	2.2	7.6	18.2
10%	1minute	18.3	10.4	6.6	16.8	32.5
	5 minutes	13.6	7.1	3.9	11.2	23.5
	10 minutes	12.4	6.6	3.5	10.6	22.7
20%	1minute	17.1	10.7	7.1	15.7	29.5
	5 minutes	13.7	8.2	4.9	12.4	24.5
	10 minutes	13.8	8.5	5.4	12.7	24.3
30%	1minute	15.7	11.1	7.3	14.6	26.2
	5 minutes	13.1	9.5	6.2	12.1	21.8
	10 minutes	12.4	9.1	5.8	11.4	20.6

As the fat content of the emulsions increases, shear time becomes less influential on mean particle size, as all three 30% emulsions are similar in particle size (d(0.5) (1minute 14.6µm, 5 minutes 12.1µm and 10 minutes 11.4 µm). However, the results still show that increased shear time leads to smaller particle size, as the results show that all the emulsions were high shear mixed from 10 minutes, regardless of fat quantity, resulted in decreased particle size when compared to the 1 minute shearing time. From these results, it is clear to see that the less fat present in an emulsion, the greater influence shear time has on resulting smaller particle size, as is apparent in the 5% fat emulsion, which gave the smallest fat particle size of 7.6µm.

The data below shows the particle size distribution per time scale.

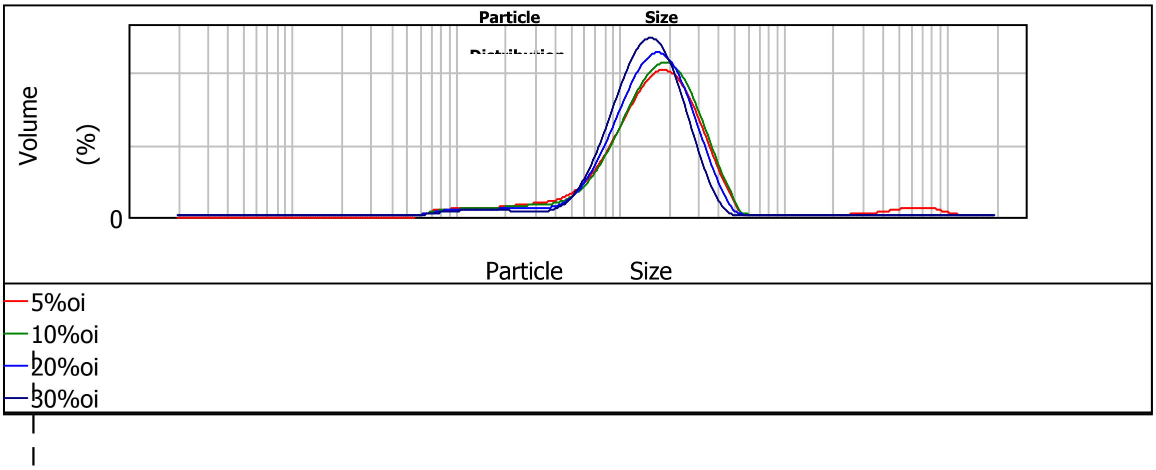


Figure 3.1: Particle Size Analysis At Shear Time 1 Minute

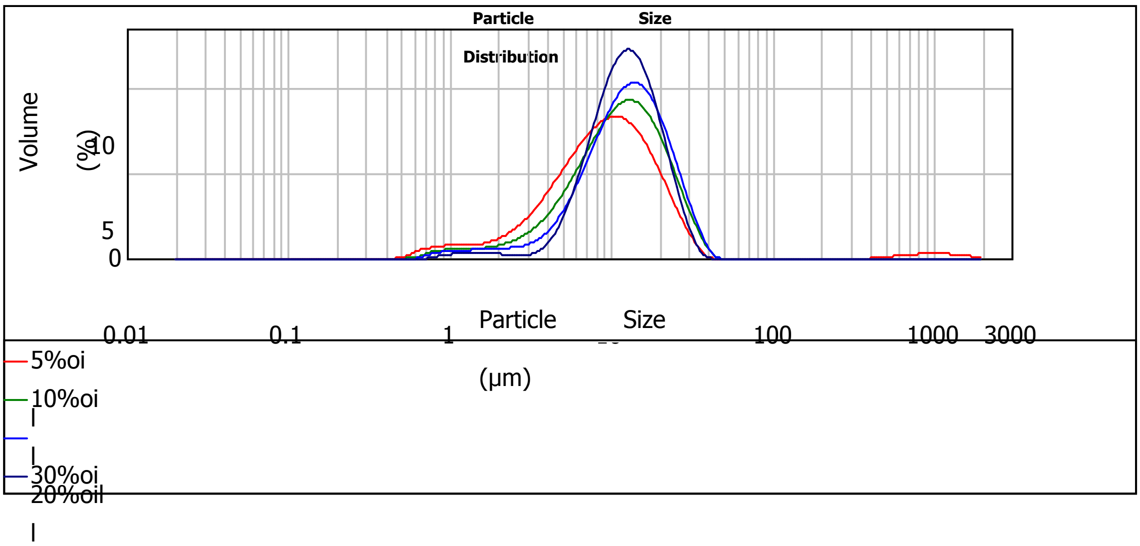


Figure 3.2: Particle Size Analysis At Shear Time 5 Minutes

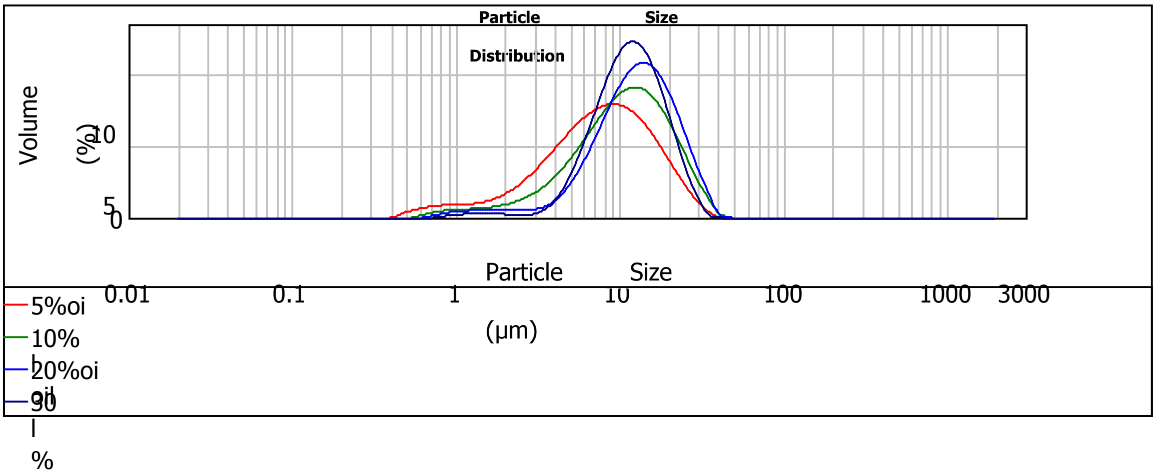


Figure 3.3: Particle Size Analysis At Shear Time 10 Minutes

Please see Chapter 3 appendix for more particle size graphs and detailed results.

3.3.2 Microscopy of Shear time experiments

Some low magnification micrographs were taken at 10x magnification of the samples at their different shear speeds. The micrographs for the 5% fat samples and the 30% fat samples are seen in the appendix. As can be seen, the increase of shear speeds leads to smaller and more uniformed fat droplets, and the increase of droplets between 5% and 30% is clear.

3.3.3 Basic emulsions with E/S mix (0.5% and 1%)

The influence of an emulsifier/stabilizer mixture on fat particle size of 4 emulsions was investigated. Two different quantities of an emulsifier/stabilizer mixture were added to 4 emulsions containing differing quantities of fat (5%, 10%, 20% and 30%). All emulsions were sheared at 10 minutes, as it was found from the results of the previous shear time experiment that increased shear time leads to smaller particle size, particularly in the case of decreased fat in emulsions.

The influence of 0.5% emulsifier/stabilizer mixture on fat particle size in 5%, 10%, 20% and 30% fat emulsions was first measured. Then the emulsifier/stabilizer mix was increased to 1% and investigate this increase in emulsifier/stabilizer mixture on fat particle size on the same emulsions. The results from these two experiments were then compared to each other dependent on fat percentage.

Table 3.7: Particle size (volume/weight) for basic emulsions 0.5% and 1% e/s mix

Fat content	E/S mix (%)	D[4,3]	D [3,2] μm	d (0.1)	d(0.5)	d(0.9)
5%	0	9.1	4.4	2.2	7.6	18.2
	0.5	2.5	1.2	0.5	2.1	5.1
	1	5.7	0.6	0.3	1.5	11.9
10%	0	12.4	6.6	3.5	10.6	22.7
	0.5	4.8	3.2	1.7	4.3	8.8
	1	2.3	1.5	0.8	2.1	4.3
20%	0	13.8	8.5	5.4	12.7	24.3
	0.5	4.3	3.2	1.9	3.9	7.4
	1	3.3	2.6	1.5	3.0	5.6
30%	0	12.4	9.1	5.8	11.4	20.6
	0.5	5.8	4.1	2.6	5.3	10.0
	1	3.0	2.5	1.6	2.8	4.7

It is apparent from the results from the two different emulsifier quantities that they both had a positive effect on decreasing the size of the fat particles in the emulsions, regardless of fat quantity. Fat particle size has decreased significantly when compared to the results of the shear time experiments, which contained no emulsifier/stabilizer mix at all. However, the results from these experiments show that the 1% emulsifier stabilizer mix produced smaller fat particles across the emulsions, regardless of fat quantity. The emulsion with the smallest particle size was the 5% fat emulsion (1.53µm), which was to be expected as it was the emulsion with the least amount of fat and therefore coated the surface of the fat globules more evenly.

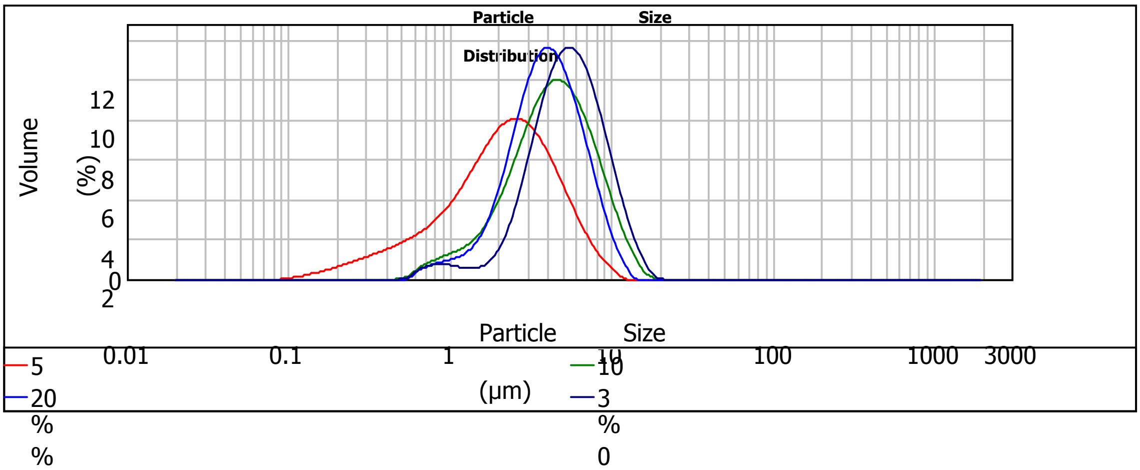


Figure 3.4: Emulsifier/stabilizer mix at 0.5%

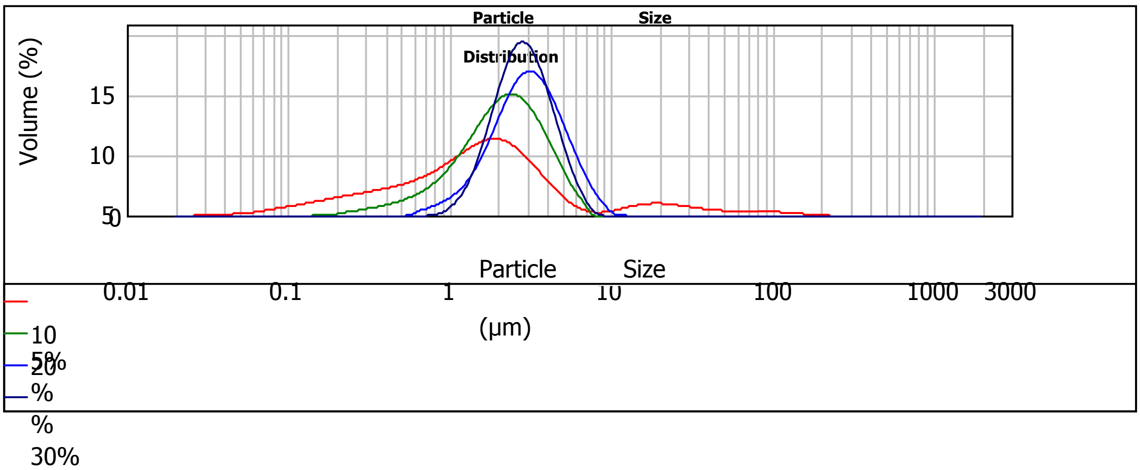


Figure 3.5: Emulisifer/stablizier mix at 1%

Please see chapter 3 appendix for more detailed results and further particle size graphs.

3.3.4 Influence of emulsifier/stabilizer mixture on creaming profile of emulsions

The creaming profiles of samples after 6, 12, 18 and 24hrs containing 0.5% e/s mix and 1% e/s mix were as follows:

Table 3.8: Creaming profiles of 0.5% e/s mix on basic emulsions

Time	Height for 30% fat sample (cm)	Height for 20% fat sample (cm)	Height for 10% fat sample (cm)	Height for 5% sample (cm)
6hr	2	4	8	13
12hr	3	6	12	13
18hr	4	8	12	13
24hr	4	8	12	13

Table 3.9: Creaming profile for 1% e/s mix on basic emulsions

Time	Height for 30% fat sample (cm)	Height for 20% fat sample (cm)	Height for 10% fat sample (cm)	Height for 5% sample (cm)
6hr	0	2	4	6
12hr	0	3	7	9
18hr	0	6.5	11	11
24hr	0.5	8.5	11	11

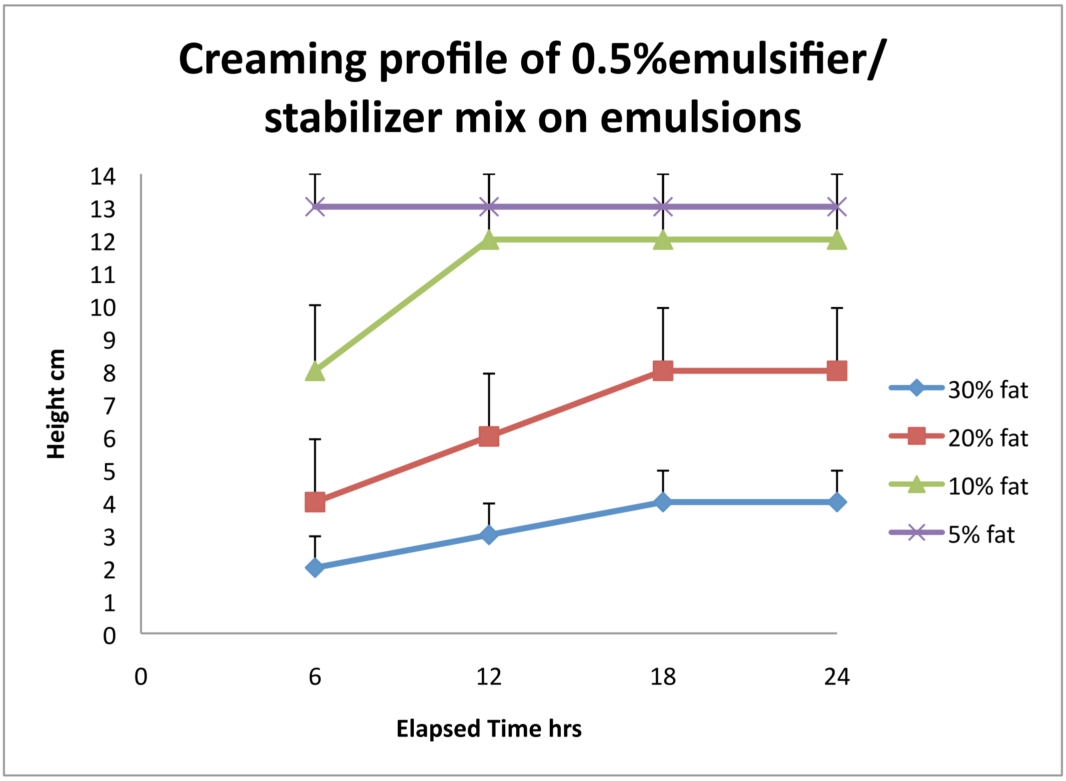


Figure 3.6: Creaming profile of 0.5% emulsifier/stabiliser mix

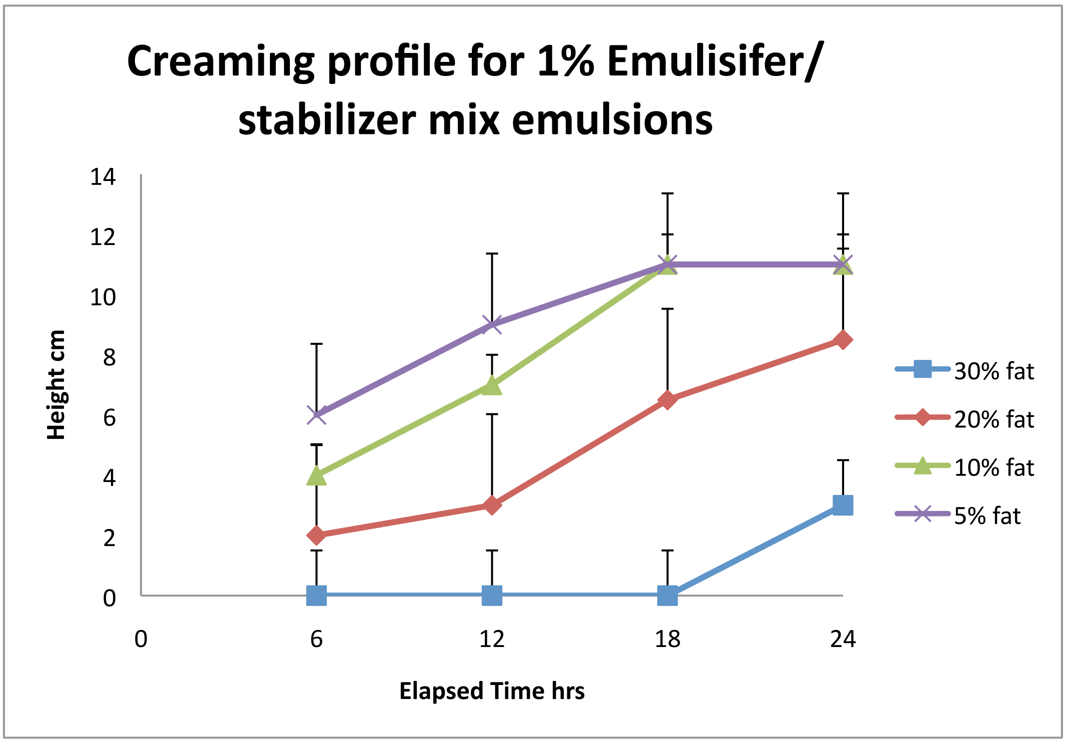


Figure 3.7: Creaming profile for 1% emulsifier/stabiliser mix

As is apparent from the creaming results, the 30% fat samples for both 0.5% e/s mix and 1% e/s mix were the most stable from all the samples as they had the least amount of serum separation. Both the 5% fat samples for both 0.5% e/s and 1% e/s had the most separation at 13cm and 11cm separation respectively. The difference between the 5% fat 0.5% e/s mix and the 1% is 2cm. It is clear that emulsion stability increased with an increased amount of emulsifier/stabilizer mixture, which is in keeping with the previous literature (Opawale & Burgess 1998). However, it is important to note that with an ice cream formulation, emulsifier is added to actually reduce the stability of the fat emulsion by replacing protein on the surface of the fat. This then leads to a thinner membrane prone to coalescence during the whipping stage of production (Goff, 2007). The reason for such long time scales was that the samples had originally been observed in terms of 15-minute blocks for an hour but there was very little data to report as no creaming was observed. It was therefore decided to push the time scales up, as there was confidence that creaming would be observed in terms of hours rather than minutes. These results allow for confidence that there will not be gross destabilisation of the fat phase of the emulsified systems, and therefore would hypothesise that it would not impact on the process of eating that much.

3.3.5 Influence of homogenization on fat particle size of emulsions

Three 30% fat emulsions were prepared and one was homogenized once, another twice and the third three times to explore the influence of homogenization on fat particle size.

Table 3.10: Particle size (volume/weight) Homogenised 30% fat basic emulsion

Homogenized (times)	D[4,3]	D[3,2] µm	d (0.1)	d(0.5)	d(0.9)
1	2.3	1.9	1.2	2.20	3.7
2	2.6	2.3	1.5	2.4	4.0
3	3.0	2.7	1.7	2.8	4.7

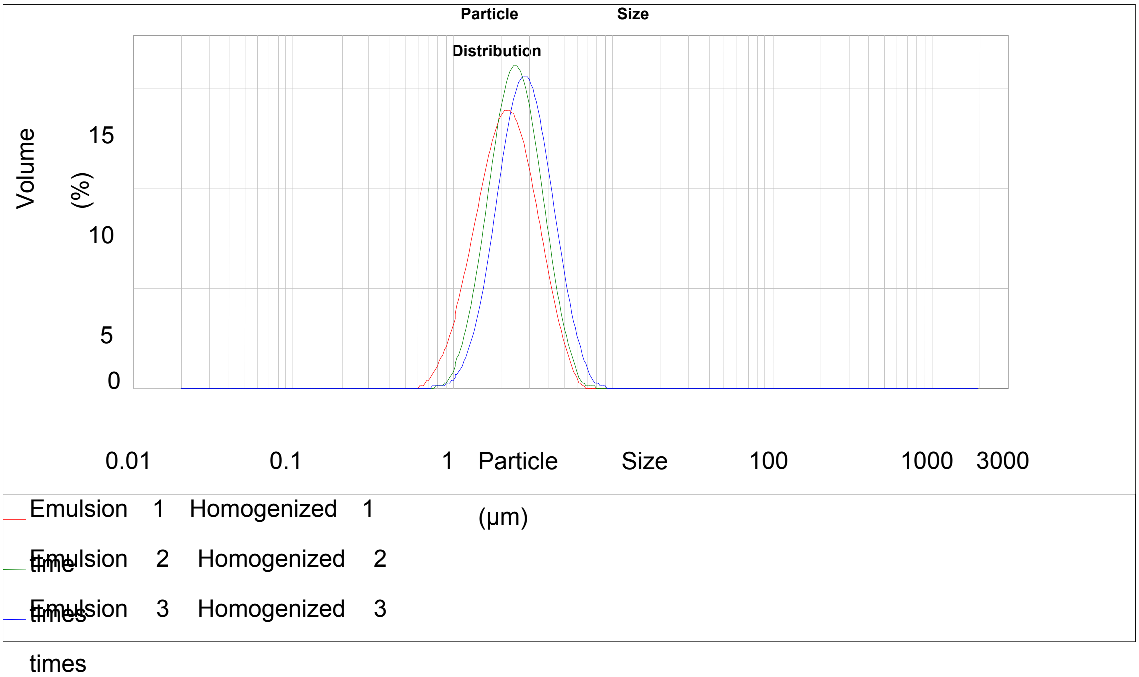


Figure 3.8: Particle size for homogenised samples

From the data above, it can be seen that the particle size of three 30% fat emulsions that has been homogenized once, twice and three times. From this it can be inferred that there is subtle and slight difference between each of the emulsions. Emulsion 1 has the particle size of 2.2 µm, the smallest of the three emulsions. Emulsion 2 has the particle size of 2.4 µm and emulsion 3 has the particle size of 2.86 µm. Whilst these results seem to indicate that less homogenization results in a smaller fat particle size, it is only by a 0.6 of a µm, and homogenization is not only important in decreasing fat particle size, but also in balancing the distribution of fat and also contributes to the stability and creaming of emulsions.

3.3.6 Homogenization on creaming profiles of emulsions

The creaming profiles of the homogenized samples were as follows:

Table 3.11: Homogenisation on creaming profiles of 30% fat emulsions

Homogenization of 30% oil	Time (hrs)	Height (cm)
1	6	0
	12	2
	18	2
	24	3
2	6	0
	12	0
	18	1
	24	3
3	6	0
	12	0
	18	1
	24	2

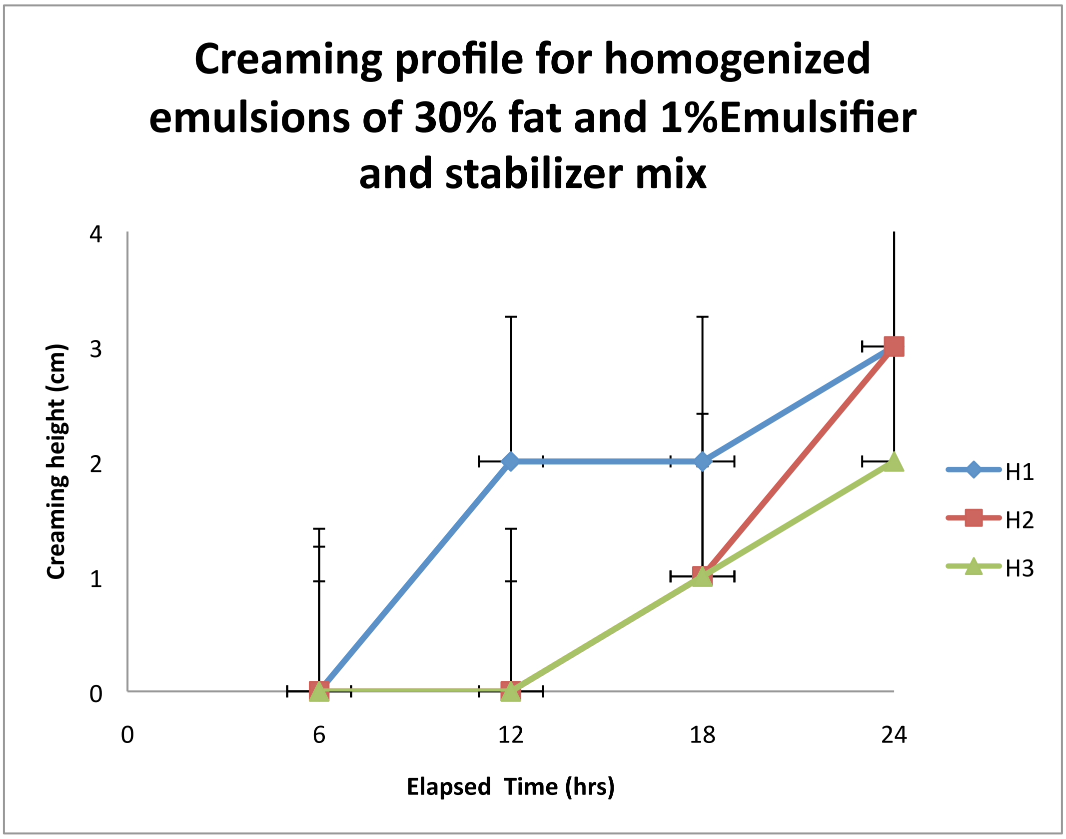


Figure 3.9: Creaming profiles for homogenised 30% fat 1% e/s mix samples

As is apparent from the above results the increased number of times the sample was homogenized, the more stable the sample became, and the less separation occurred. This is in keeping with the pervious results of Goff (2007) who found that 2-stage homogenization reduced the impact of flocculation of the fat globules, which can occur during the first stage of homogenization. However, when compared to the results of the previous emulsifier/stabilizer experiment, the same sample, which had not been homogenized at all, remained more stable with only 0.5cm of separation. This is not in keeping with previous literature, however, could have been down human error when preparing the samples.

3.3.7 Tribology results

In we can see the response of the tribometer to the Green & Blacks vs. Sainsbury's basics at 37°c which replicates in mouth temperature. From this graph we can identify that that the traction coefficient begins higher in both samples when ball speed is low, but as speed increases the traction coefficient become decidedly lower. The traction coefficient begins higher for the Green & Blacks sample than the Sainsbury's, which could be due to the difference in fat types between the samples. From this graph we can identify that the Green & Blacks ice cream at 37°c has a sufficient lubrication beginning at 0.25 traction coefficient and steadily decreasing as ball speed increases, decreasing to below 0.05. The Sainsbury's sample has decidedly more lubrication, as the traction coefficient for the Sainsbury's sample begins lower than the Green& Blacks at just under 0.2. This could be down to the use of palm oil in the ice cream.

Whilst this graph cannot tell us about perceived creaminess, it could be hypothesized from this graph that the Green & Blacks ice cream would give a fuller and longer lasting mouth feel than the Sainsbury's basics as the traction coefficient for the Sainsbury's basics is lower, and would therefore it could be perceived as more lubricating. However, it was decided that due to the fact that the Green & Black sample contained vanilla seeds that can act as a visual cue to human participants, this ice cream would not be carried forward to future experiments. Also, when compared with tribology results in Chapter five, these ice creams actually indicated similar results than the ice creams used in later experiments.

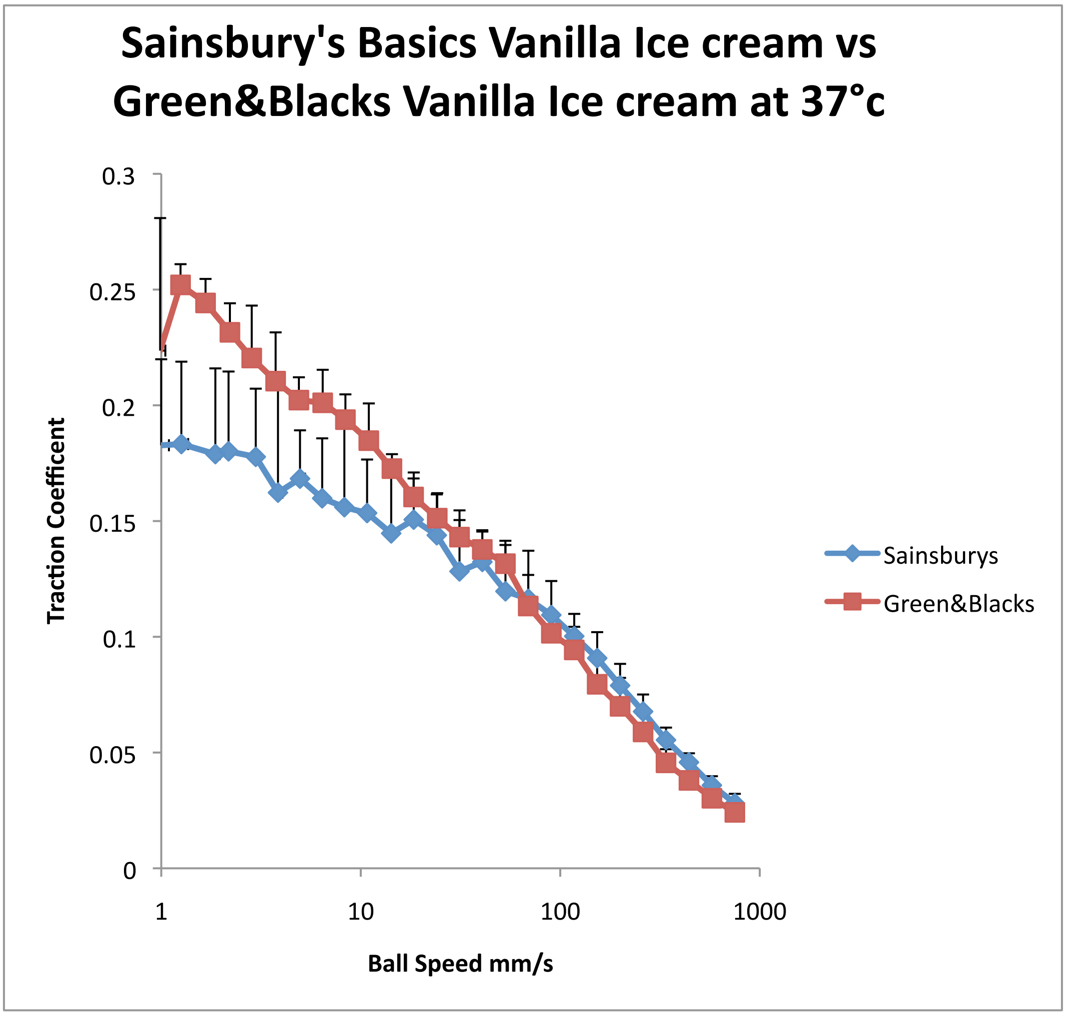


Figure 3.10: Tribometer results for Sainsbury's basics and Green & Blacks samples at 37°c

These experiments sought to gain a better knowledge of the material properties of ice cream emulsions, and to test the stability of these emulsions over time. The inclusion and use of emulsifiers and stabilizers solidified their necessity in these emulsions, leading to increased emulsions stability. Also, the importance of homogenisation was corroborated and in keeping with the findings of previous authors such as Goff (2007), and shows that homogenisation is not only important for decreasing mean fat particle size, but also contributes to emulsion stability.

From these experiments it can be concluded that the material properties of basic ice cream emulsions over the time scales were stable enough to carry forward to future experiments, and confidence was gained in the background of the material properties and their purpose.

CHAPTER 4: EATING BEHAVIOUR INVESTIGATIONS

4.1 Analysis of commercially available ice cream eating behaviour through a repeated measures design

The results gathered in the previous chapters has allowed the scope for further investigation into ice cream eating behaviour and to gauge an understanding into whether different formulated ice creams impact on consumer responses such as rate of intake. Results from Chapter 2 also indicated which ice creams would be best to carry forward for future research. From this, a repeated measures design was carried out between Sainsbury's basics ice cream (low quality) and Mackie's of Scotland (high quality) with the portion size 200g being used.

From this, a repeated measures investigation into the palatability and sensory attributes of two demonstrably different ice creams can be better understood, which could lead to improvements in formulations and adding to research within the eating behaviour sector as research into ice cream and on a whole, sweet/dessert foods, is sparse. Whilst there has been a plethora of research into meal-based foods, such as pasta, researching the effects of satiety, there is little known about 'treat' foods, such as ice cream. These types of foods are not best understood in terms of satiety (the time between one meal and the next), but perhaps better related to satiation (the decision to terminate eating at a specific time due to feeling full).

The significance of using the Mackie's was that it scored the highest on the taste test, and the Sainsbury's as it was the better of the lower qualities variants. The reason the absolute lowest scoring ice cream was not chosen, was that there was a concern due to the very low quality that participant, as on the taste test, i.e. poor scores, would reject it. By separating these ice creams into slightly subjective 'quality' categories, it is attempting to encompass the spectrum of taste/texture/palatability/formulation/ingredients/nutritional value of the ice creams into one term. It was decided that due to the interdisciplinary nature of the experiments carried out, the results would be set out in both tabular and figure form for ease of reading and understanding from both disciplines.

4.1.1 Hypothesis

H1: There will be significant difference in the palatability scores, rate of intake and total intake between two commercially available ice creams, one of demonstrable high quality and one of lower quality with the higher quality ice cream scoring higher than the lower quality. Within meal VAS scores for enjoyment, hunger and fullness will also be investigated. Energy density differences between the ice creams will also be looked at.

4.1.2 Methodology

4.1.2.1 Participants

A total of 38 participants (all female, all students) were selected from Birmingham University. However, due to errors, which only became apparent during data analysis, only 31 data sets could be brought forward for analysis. The participants were obtained using a purposive sampling method. An advert was placed on the University of Birmingham online participation scheme where students could sign up to the study. Restricted eaters and males were excluded. This was because including restricted eaters may have influence the results and previous research has indicated that males can sometimes over eat compared to female participants which would have skewed the results, so it was felt that it would be best to exclude these two groups of people from the participant population. Restricted eaters were also excluded using scores from the Dutch eating behaviour questionnaire that all participants completed. Smokers and people with food allergies were also excluded, as it could not be guaranteed that the ice creams used would have been safe for them to eat. Participants were also randomly allocated into low/high quality groups on their first session, with them changing groups on their second session. Participants were not aware of which groups they had been allocated. Average age; Body mass index (BMI) and Dutch Eating Behaviour Questionnaire scores (DEBQ) for participants are shown in the table below. All of these measurements were taken following the completion of the last session. Please see Chapter 4 appendix for DEBQ scale and advert. The DEBQ is a questionnaire designed to assess an individuals eating behaviour through three different scales; emotional, external and restrained eating. Raw scores are obtained by adding the scores of the items on the liker scale.

Table 4.1: Age/BMI/DEBQ results

Age	20.1±0.3
BMI	24±2.3
DEBQ Score (Restraint/emotional)	2.1±0.3/2.6±0.4

4.1.2.2 Ice creams

Ice creams were chosen on the basis of the previous taste test research, in which two higher quality and two low quality ice creams were tested. The highest scoring high quality (Mackie's) ice cream was chosen, as was the highest scoring low quality ice cream (Sainsbury's). The reason for choosing the higher low quality ice cream was that it was probable the lower scoring ice cream may have been totally rejected by participants. The table below shows the nutritional composition of the two ice creams.

Table 4.2: Nutritional composition of ice creams

(All details accurate at time of use, 2012-2013)

	Mackie's (High quality) 100g	Sainsbury's (Low quality) 100g
Price (£)	0.29	0.04
Energy kcal	204kCal	134kCal
Energy kJ	855kJ	565kJ
Protein	3.6kj	2.5g
Carbohydrate	23.2g	19.7g
of which sugars	20.8g	17.5g
Fat	10.8g	5.1g
of which saturates	3.1g	3.2g

4.1.2.3 Design and procedure

A repeated measures design was employed (refer back to chapter 2 for definition of repeated measures design if necessary). Dependent variables were palatability scores, rate of consumption and total intake, the latter measured in grams.

Independent variable remained the quality of ice cream, high or low. Two ice creams, the ‘low quality’ Sainsbury's Basics Vanilla ice cream (Kcal 134/100g, fat 5.1g/100g, Price 0.045/litre) and ‘high quality’ Mackie’s vanilla ice cream (Kcal 204/100g, fat 10.8/100g price 2.97p/litre) were defined. Participants were given a 200g portion of the ice cream, unlabelled, in a bowl with a tablespoon. A Sussex Ingestion Pattern Monitor/universal eating monitor (SIMP/UEM) was used to gather micro structural eating behaviour data, and Visual Analogue Scales gathered data on palatability, sensory ratings and appetite. Participants were unaware of the universal eating machine presence until completion of the experiments. Samples were weighed automatically on a concealed digital balance (Sartorius BP 4100), connected through a serial connected dell desktop computer, which was custom-programmed using Future Basic (Staz Software) to read the balance weight to 0.1 g accuracy during the consumption of the test meal. Student information pack-consent form, ethics sheet, volunteer information sheet were also handed out. Please see Chapter 4 appendix for these. Participants arrived at testing room and were asked to read a volunteer information sheet and asked to read and sign a consent form. They were then taken into a small room and asked to sit in front of the computer screen. In front of them was a placemat, which has the universal eating monitor concealed underneath it. The participants were unaware of the universal eating monitor. The experimenter then explained that the participant should follow the on screen instructions. This included a brief introduction to the experiment and a series of pre sample appetite and mood scale questions on a sliding visual analogue scale between 1-100. These were rated in the form of ‘How <word> are you feeling?’ and the words were ‘sad/happy/excited/relaxed bloated/nervous/stressed ‘ which appeared in a random order, with ‘Not at all’ and ‘Extremely’ being live anchors. All ratings were scored automatically from 0(not at all) to 100 (extremely). After these had been completed, an instruction appeared to ‘call the experimenter’ by ringing a doorbell that was placed to the right of the table and samples would be brought to them. This was followed by participants being presented with a small taste test sample of the ice cream related to which group they had been placed in-low or high quality. Following the taste test sample, sensory attribute and enjoyment questions were asked, again on a sliding visual analogue scale of between 1-100. These questions were rated in the form of ‘How <word> is this ice cream’? Participants were then given an undisclosed amount of unlabelled sample of the same ice cream (200g) and asked to eat *ad libitum*. Whilst eating, participants were signalled to answer further appetite and enjoyment visual analogue scale questions every 25grams of ice cream eaten. These appeared in the form of ‘How <word> are you feeling now? The words were ‘hungry and full’ and ‘How much are you enjoying this ice cream?’ This repeated pattern of consuming 25g portions and then completing appetite ratings continued until the total weight consumed, or until the participant terminated eating, whichever came first. Participants were also asked not to leave their spoon in the bowl at any time. Meal termination was signalled by participants using the computer mouse to click on a button marked “Finished”, which was present on the screen throughout the meal. Once eating was completed, participants re-rated their mood and appetite using the same scales as at the start of the test. Two other questions were also added to this series of visual analogue scale questions, which were ‘how likely would you be to purchase this ice cream' and 'how much did you enjoy this ice cream'. Participants then returned between 24-36hrs after for their second session, following which height and weight of the participant was taken. Participants were then thanked and debriefed.

4.1.2.4 Palatability/sensory measurements

These were asked in the format of a digital sliding visual analogue scale from 1-100 following the taste test sample. These included questions on creaminess, visual pleasantness, sweetness, and taste pleasantness, and strength of vanilla flavour.

After every 25g of ice cream eaten, the participants were asked to rate their appetite and enjoyment on a sliding visual analogue scale from 1-100. These questions were 'how hungry are you?', 'how full do you feel now?', and 'how much are you enjoying this ice cream?'.

Other questions also included likelihood to purchase and how much they enjoyed the ice cream.

4.1.2.5 Ethics

All British Psychological Society (2005) guidelines were adhered to, and informed and written consent was gained from each participant. An ethics certificate was also gained from Birmingham University. All participants were verbally informed, and it was explained that participation was not compulsory. All participants were told that they had the right to withdraw from the study at any time without consequence. Participants were also debriefed after the study. All were thanked for their participation in the study. All information gathered was kept confidential and anonymity was observed.

4.1.2.6 Data analysis

A repeated measures t test was carried out to test if there was a significant difference in the palatability scores, rate of intake and total intake between two commercially available ice creams of demonstrably different quality. Changes in rated appetite/fullness and enjoyment within the meal and the rate of intake was also examined using a two way repeated ANOVA design. All analysis was conducted on SPSS version 21 on an apple Macintosh Mac book air.

4.1.3 Results

4.1.3.1 Mood ratings

Table 4.3: Mood ratings pre session

Ratings	Sainsbury's (Means & Standard Error)	Mackie's (Means & Standard Error)
BLOATED	34.9±4.2	31.6±4.3
EXCITED	46.9±4.4	42.0±3.9
TIRED	55.7±4.0	51.0±4.9
HAPPY	64.6±3.2	64.6±2.7
STRESSED	38.5±4.3	34.1±3.7
SAD	22.3±4.2	22.4±4.0
NERVOUS	21.8±4.6	19.4±3.4
RELAXED	63.1±4.2	62.5±3.6

Table 4.3 shows the means and standard deviation for mood ratings taken at the start of both ice cream sessions. There were no significant differences found in these ratings at the start of either session. Here are the statistical results from the pre meal mood ratings comparing the two ice creams. BLOATED [t(30)=0.706, P>0.05], EXCITED[t(30)=-.122, P>0.05], TIRED[t(30)=0.642, P>0.05], HAPPY [t(30)=-1.06P>0.05], STRESSED [t(30)=0.79, P>0.05], SAD[t(30)=-0.015 P>0.05], NERVOUS[t(30)=0.48, P>0.05], RELAXED[t(30)=0.121, P>0.05]

Table 4.4 shows the mood ratings taken at the end of both sessions, and indicates a significant difference on RELAXED rating, [t(30)=-2.2, P<0.05], but no significant difference in any of the other ratings. BLOATED [t(30)=1.23, P>0.05], EXCITED[t(30)=-.71, P>0.05], TIRED[t(30)=0.07, P>0.05], HAPPY [t(30)=-0.98,P>0.05], STRESSED [t(30)=1.15, P>0.05], SAD[t(30)=0.49 P>0.05], NERVOUS[t(30)=0.31, P>0.05]

Table 4.4: Mood ratings post session

Rating	Sainsbury's (Mean &Standard Error	Mackie's (Mean & Standard Error)
BLOATED	51.8±4.5	46.8±4.9
EXCITED	46.1±4.1	49.9±3.8
TIRED	50.4±4.3	49.8±5.2
HAPPY	70.3±3.4	74.3±3.0
STRESSED	28.6±4.2	23.6±3.5
SAD	17.4±3.6	15.5±3.1
NERVOUS	16.1±3.5	14.9±3.3
RELAXED	69.3±3.7	77.9±2.6

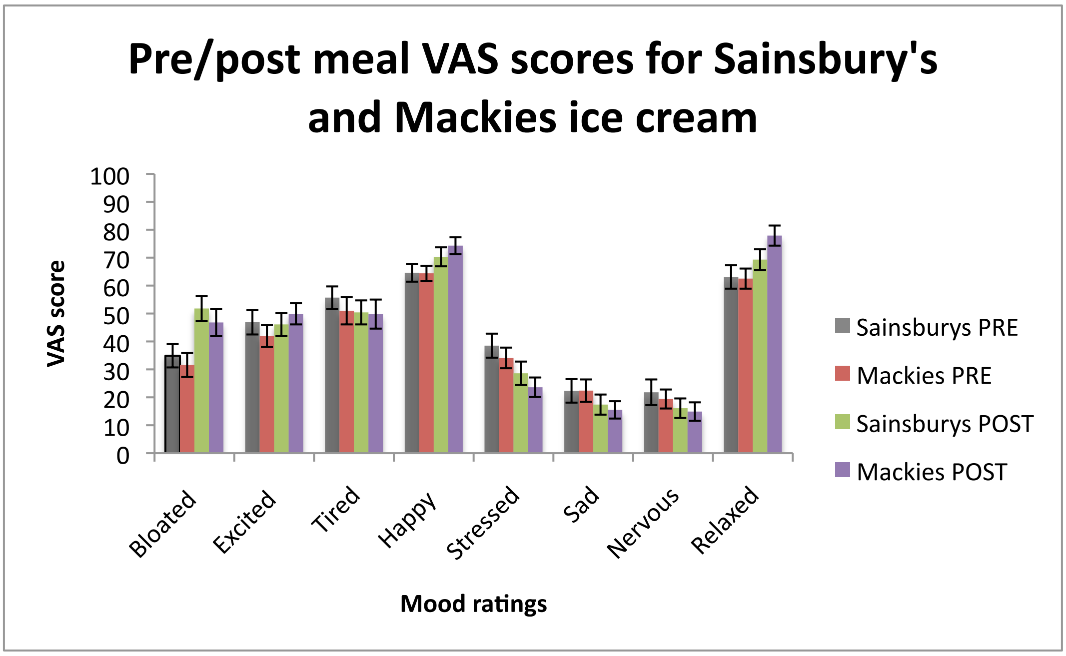


Figure 4.1: Mood ratings pre/post sessions

4.1.3.2 Palatability ratings

Analysis of the palatability ratings showed differences in one of the five palatability attributes between the ice creams. This was on the CREAMY rating [$t(30)=-3.0$, $P<0.05$], with the Mackie's ice cream scoring a higher rating [M=77.7±1.8]. Table 4.5 shows the mean palatability ratings between the ice creams.

Table 4.5: Palatability ratings

Ratings	Sainsbury's (Mean & Standard error)	Mackie's (Mean & Standard error)
CREAMY	64.0±4.0	77.7±1.8
VISUALLY PLEASING	52.5±3.3	57.7±4.3
SWEET	69.3±2.5	67.7±2.5
PLEASANT	73.8±2.6	78.1±2.3
VANILLA FLAVOUR	61.7±3.5	65.6±3.0

VISUALLY PLEASING rating [$t(30)=-1.03$, $P>0.05$], SWEET rating [$t(30)=0.57$, $P>0.05$], PLEASANT rating [$t(30)=-1.41$, $P>0.05$] and VANILLA FLAVOUR rating [$t(30)=-0.93$, $P>0.05$]

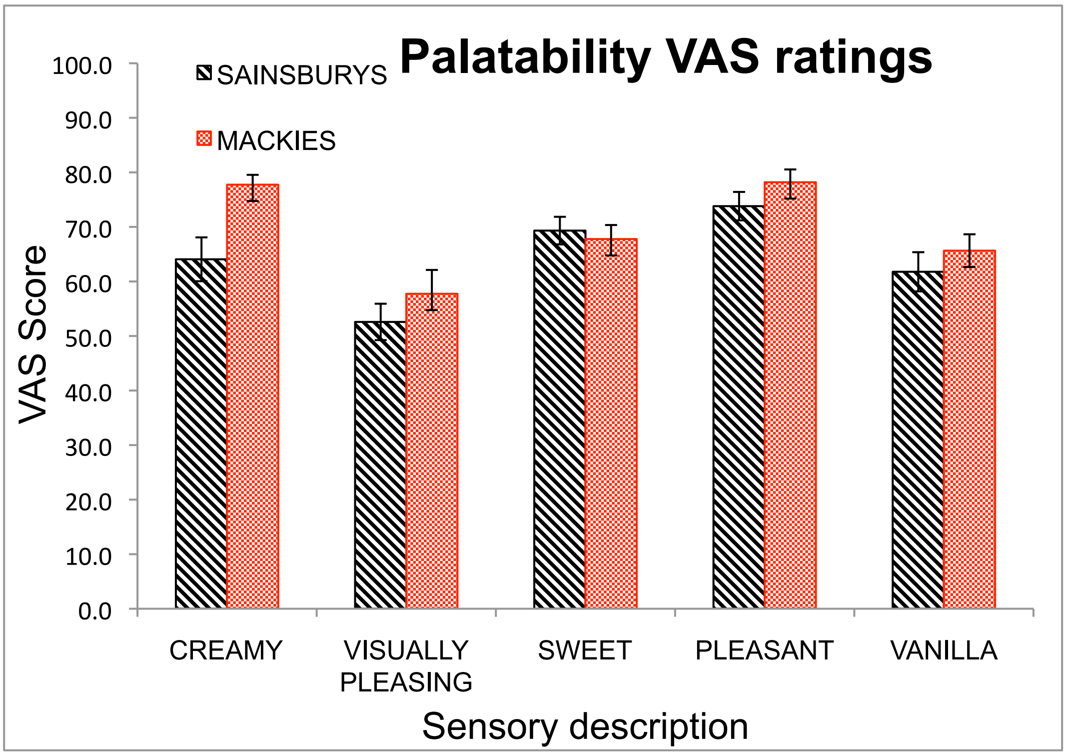


Figure 4.2: Palatability VAS ratings

There was also a significant difference found between the ice creams with regards to 'Likelihood to purchase' [t(30)=-2.3, P<0.05] with Mackie's scoring a higher mean rating [M=65.5±3.9] when compared to Sainsbury's [M=51.6±4.7].

4.1.3.3 Overall Food Intake and rate of intake

Overall mass consumed between the ice creams was not significantly different [t(30)=-0.187, P>0.05] with participants consuming almost identical mean gram amounts of both ice creams [Sainsbury's M=83.0±9.1, Mackie's M=84.7±8.4]. However, when expressed in terms of energy density intake, there was a significant difference between the ice creams [t(30)=-3.9, P<0.001]. The average energy consumed from the Sainsbury's ice cream was 469kj±51.4 compared to 724kj±72.4 of the Mackie's. Below is a graph displaying the average energy consumed.

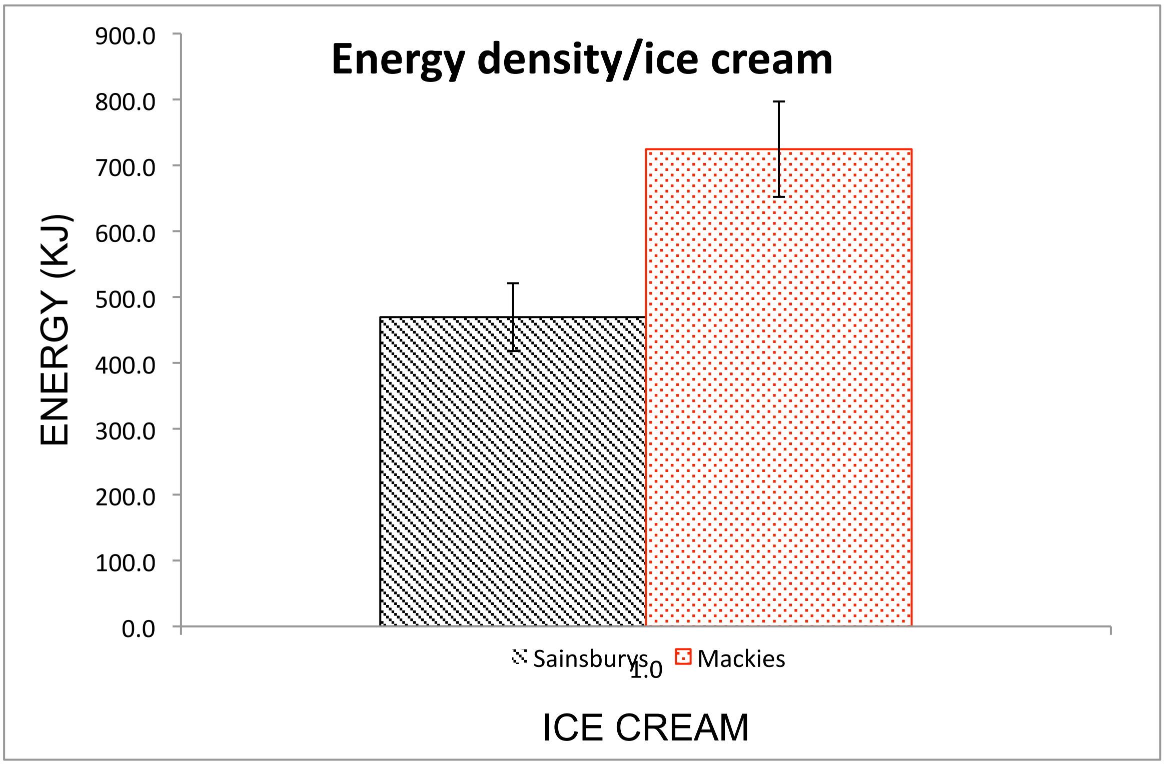


Figure 4.3: Energy density of ice creams

is indicated Rate of intake in Figure 4.4 below. Difference in rate of intake was measured minute against minute for each ice cream and found no significant difference in the rate that either ice cream was eaten over 11 minutes. Table 4.6 shows the descriptive statistics for the rate of intake between the ice creams.

Table 4.6: Average rate of intake (grams per min)

Minute	Sainsbury's (Means & Standard Error)	Mackie's (Means & Standard Error)
1	17.0±3.0	16.2±2.6
2	35.0±4.6	36.3±4.8
3	51.8±5.3	51.0±5.1
4	60.3±5.5	62.3±4.9
5	69.1±6.6	70.0±5.5
6	74.8±7.6	75.6±6.5
7	78.8±8.2	79.4±7.2
8	80.9±8.6	81.8±7.6
9	82.6±8.9	83.4±8.0
10	83.1±9.1	84.1±8.2
11	83.1±9.1	84.7±8.4

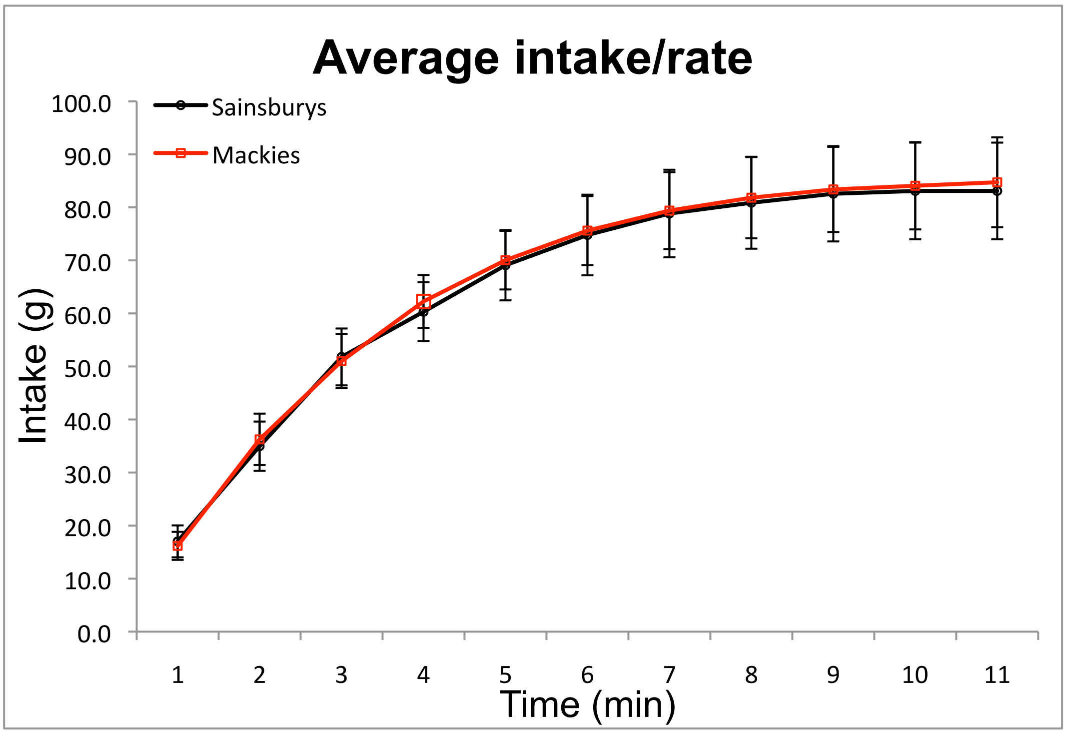


Figure 4.4: Average rate of intake

4.1.3.4 Changes in within meal rated appetite

Pre meal ratings in hunger and fullness found no significant difference between the conditions [t(30)=1.04, P>0.05] [t(30)=-0.76, P>0.05]. However, pre meal ratings for enjoyment did show a significant difference between conditions [t(30)=-2.6, P<0.05], with Mackie's scoring higher. Table 4.7 shows the means and stand errors for pre meal ratings.

Table 4.7: Pre meal hunger/fullness ratings

RATINGS	Sainsbury's (Means & Standard Error)	Mackie's (Means &Standard Error)
ENJOYMENT	71.3±3.0	80.3±2.2
HUNGER	53.8±4.3	48.2±4.3
FULLNESS	39.6±4.3	44.0±4.6

Within meal data for ENJOYMENT, HUNGER AND FULLNESS were then broken down into meal quartiles, including the pre meal rating through to the four quartiles. Descriptive statistics can be found in Table 4.8

Table 4.8: Within meal data in quartiles

Quartile	Sainsbury's (Means& Standard Error) (Enjoyment/hunger/fullness)	Mackie's (Means& Standard Error) (Enjoyment/hunger/fullness)
Pre	71.3±3.0/53.8±4.3/39.6±4.3	80.3±2.2/48.3±4.3/44.1±4.6
1	65.4±3.9/40.5±3.6/52.1±3.6	75.0±3.2/47.1±3.5/51.2±3.7
2	66.6±3.5/33.1±3.4/62.9±3.4	72.3±3.1/39.5±3.7/57.7±3.6
3	64.9±3.4/26.6±3.2/70.5±3.5	72.2±2.8/36.3±3.9/62.8±3.7
4	66.5±3.9/19.9±3.6/77.7±3.3	74.6±3.4/30.2±4.5/70.5±4.0

Using a two way repeated ANOVA for analysis, within meal enjoyment scores quartiles were compared. There was no interaction between ice cream and quartiles on enjoyment scores. [Wilks Lamdba= 0.82, F(4,27)=1.3, P>0.05, partial eta squared=0.17]. There was a main effect for quartiles [Wilks Lambda=0.64, F(4, 27)=3.6, P<0.05, partial eta squared=0.35] and a main effect for ice cream [Wilks Lambda=0.85, F(1, 30)=4.9, P<0.05, partial eta squared=0.14]. Further analysis through pair wise comparisons found that significant difference in enjoyment ratings were found in pre meal ratings and quartile 1[t(30)=-2.27, P<0.05] with enjoyment rating being on average higher on Mackie's than Sainsbury's in this quartile.

Within meal hunger ratings then showed that there was an interaction between the ice cream and quartiles [Wilks Lamdba=0.58 , F(4,27)=4.7, P<0.05, partial eta squared=0.41]. There were no main effects for ice cream [Wilks Lambda=0.94, F(1,30)=1.8, P>0.05, partial eta squared=0.05] but there was a main effect of quartiles [Wilks Lambda=0.34, F(4, 27)=12.7, P<0.05, partial eta squared=0.65]. This is to be expected as intake increases, hunger ratings decrease across the quartiles. Further analysis through pair wise comparison found that significant difference in hunger ratings were found between quartile 3[t(30)=-2.32, P<0.05] and quartiles 4 [t(30)=-2.22, P<0.05] with hunger ratings decreasing more with Sainsbury's than Mackie's.

Within meal fullness showed that there was no interaction between the ice creams and session[Wilks Lamdba=0.72 , F(4,27)=12.5, P>0.05, partial eta squared=0.27]. There was no main effect for ice cream [Wilks Lambda=0.98, F(1,30)=0.53, P>0.05, partial eta squared=0.01]. There was a main effect for quartile[Wilks Lmabda=0.18, F(4,27)=29.1, P<0.05, partial eta squared=0.81] but this was not dependent on ice cream.

Below are graphs indicating within meal ENJOYMENT, HUNGER AND FULLNESS.

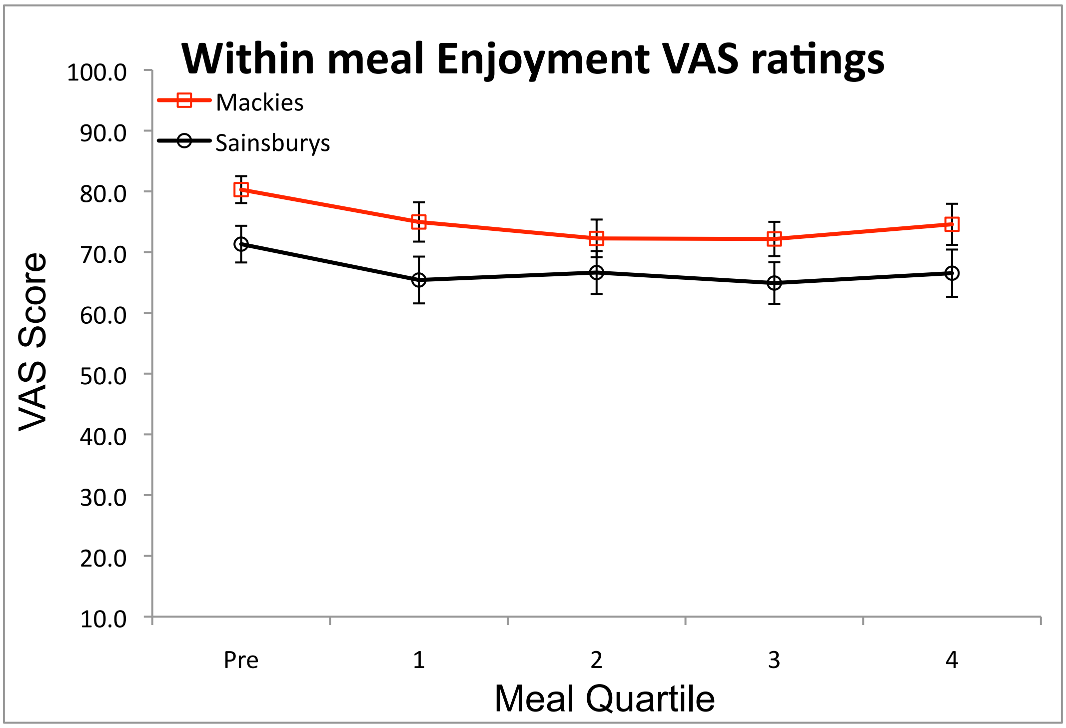


Figure 4.5: Within meal Enjoyment

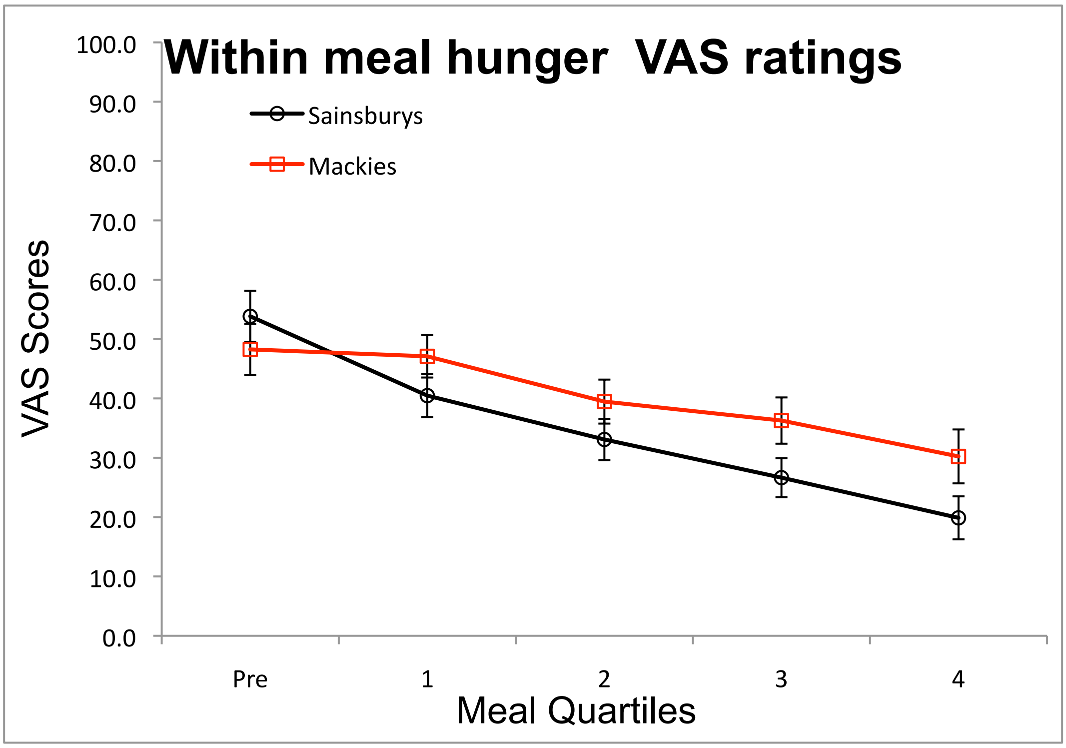


Figure 4.6: Within meal hunger

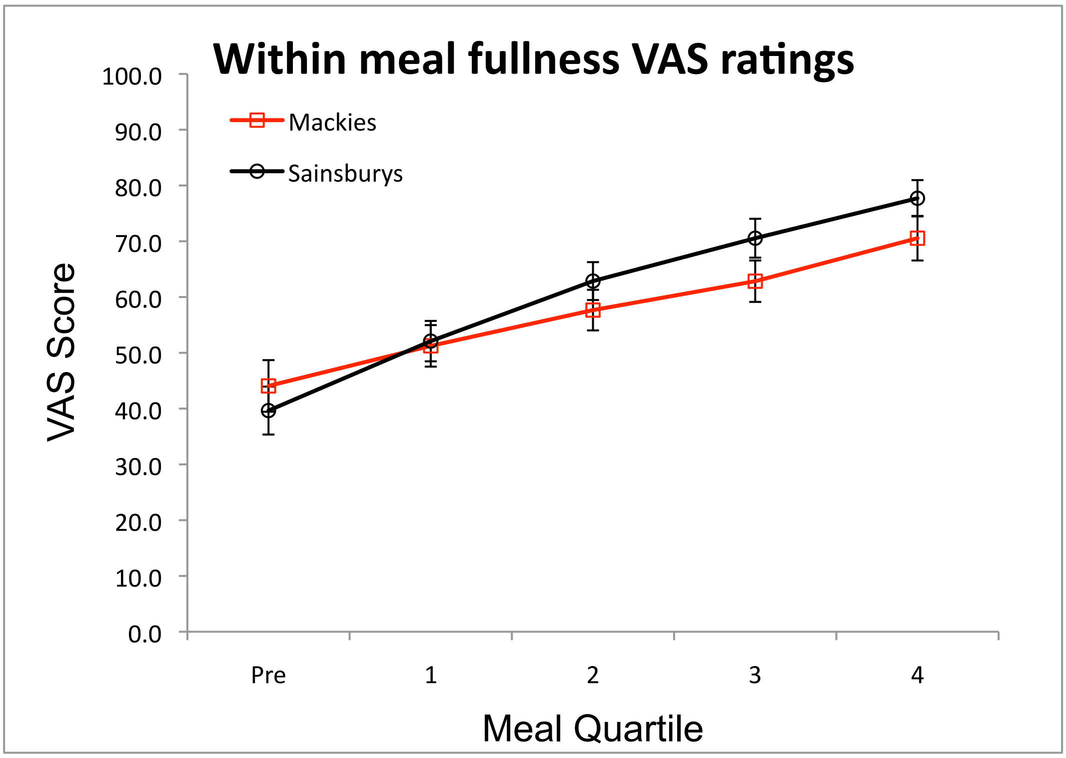


Figure 4.7: Within meal Fullness

4.1.4 Discussion

Hypothesis stated that there would be significant difference between the palatability scores, rate of intake and total intake between two commercially available ice creams, one of high quality (Mackie's) and one of lower quality (Sainsbury's) with the higher quality ice cream scoring higher than the lower quality. Within meal VAS scores for enjoyment, hunger and fullness will also be investigated.

From the results gathered, the above hypothesis needs to be rejected, as there was no significant difference found in rate of intake, total intake and four out of the five palatability measurements. The only palatability measurement that was found to score a significant difference between the ice creams was creaminess, with

Mackie's scoring significantly higher rating than the Sainsbury's. Creaminess is a difficult term to define, however physical data gathered in Chapter 5 allows some understanding to be gathered about the difference in 'creaminess' between the ice creams. Results also indicated that whilst there was a significant difference in the energy density consumed between the ice creams, this did not affect the overall amount eaten. This means that participants did not adjust the amount they consumed dependent the energy density of the ice cream. This failure to adjust the amount eaten to regulate energy intake is also seen in research conducted by Bell *et al* (1998) found that when normal-weight women consumed test lunch or dinner foods, which varied in energy density, the total weight of food consumed did not vary, resulting in significantly higher energy intake in the higher energy density condition. This is therefore satiation and not satiety. There was also a significant difference found with regards participants scores regarding 'likelihood to purchase', with Mackie's, the higher quality ice cream, scoring higher. Within meal hunger ratings also showed a significant interaction between ice cream and quartiles within the meal, with hunger decreasing more with the Sainsbury's ice cream, which was the less energy dense ice cream, which was not expected.

There are several possibilities as to why the creaminess scores were different between the ice creams. Firstly, as Goff (2008) previously indicated, that fat is vital to the structure and delivery of flavour and mouth feel. The two ice creams used in this experiment not only had different types of fat, but also different overall fat contents, with the higher quality ice cream having the higher fat content, and also, the more highly desirable type of fat (cream) for a 'creamy' mouth feel, when compared to the vegetable fat of the lower quality ice cream. This could indicate as to why the scores for the higher quality ice cream were significantly different on creaminess and likelihood to purchase. But it was expected that the higher quality ice cream would score higher on other sensory/palatability attributes, such as sweetness, visual pleasantness and vanilla flavour. The evidence that it there were no significant differences is intriguing and warrants further investigation, as does the effect on rate of eating and intake if participants were exposed to the ice cream over several sessions, as again, there were no significant difference between these either. Previous research indicates that the more palatable a food is, the greater the increase in intake amount and rate. Even though the palatability scores were only significant for creaminess, this did not seem to impact on rate or total intake of the ice creams. This led to a second, mixed-between design study to be carried out to test the effect of ice cream formulation and time (exposure to ice cream) on palatability and rate of eating.

4.2 Analysis of commercially available ice cream eating behaviour through a Mixed-between Analysis of Variance experimental design

4.2.1 Hypothesis

H2: There will be significant difference in the palatability scores, rate of intake and total intake between two commercially available ice creams, one of demonstrable high quality and one of lower quality over time and number of exposures. Within meal VAS scores for enjoyment, hunger and fullness will also be investigated. Energy density in relation to total intake will also be investigated.

4.2.2 Methodology

4.2.2.1 Participants

A total of 30 participants (all female, all students) were selected from Birmingham University. An advert was placed on the University of Birmingham online participation scheme where students could sign up to the study. Restricted eaters and males were once again excluded. Participants that took part in the initial part of the study (the repeated measures study) were also excluded from this study, as there was potential for learning effect, and remembered the purpose objective for the first experiment. Smokers and people with food allergies were also excluded. Participants were also randomly allocated into low/high quality ice cream groups on their first session, and remained in this group for the duration of the study. They were not aware of which groups they had been placed in. Average age; Body mass index (BMI) and Dutch Eating Behaviour Questionnaire scores (DEBQ) for participants are shown in the table below. All of these measurements were taken following the completion of the last session.

Table 4.9: Age/BMI/DEBQ scale

Age	19±0.13
BMI	23±0.53
DEBQ Score (Restraint/emotional)	2±0.13/2±0.10

4.2.2.2 Ice Creams

The two ice creams were again, the ‘low quality’ Sainsbury's Basics Vanilla ice cream (Kcal 134/100g, fat 5.1g/100g, Price 0.45p/litre) and ‘high quality’ Mackie’s vanilla ice cream (Kcal 204/100g, fat 10.8/100g price 2.97/litre) remained the same as the previous repeated measures study.

4.2.2.3 Design and procedure

A 'mixed within-between design' was employed. This is defined as being used when 'there are a mixture of one between group variables, one within group variable and dependent variable' (Pallent, 2007). Participants were randomly allocated into one of two ice cream groups (High quality vs. Low quality,) and were tested over 3 days. The order of testing was counterbalanced, with between 24-36hrs between each session. Between group factor was the ice cream (high quality vs. low quality) and within group factor was time (session1/2/3). Dependent variables included mood scores, palatability scores, rate of consumption and total intake, the latter measured in grams. Experimental procedure remained the same as the previous repeated measures study, but participants attended a third session, 24-36hrs after the second. The palatability/sensory measurements also remained the same.

4.2.3 Results

4.2.3.1 Mood Ratings

A mixed between-within ANOVA was conducted to assess if there were any difference present in pre meal mood ratings across the three sessions between the ice cream conditions.

For BLOATED rating, there was no significant interaction between session and ice cream [Wilks Lambda=0.907, $F(2, 27)=1.37$, $P>0.05$, partial eta squared=0.93].

There was no significant main effect for session [Wilks Lambda=0.910, F(2, 27)=2.80, P>0.05, partial eta squared=0.90]. The main effect for ice cream was also not significant [F(1, 28)=0.155, P>0.05, partial eta squared=0.005]suggesting no difference in BLOATED rating between the two ice creams.

For EXCITED rating there was no significant interaction between session and ice cream [Wilks Lambda=0.986, F(2, 27)=0.19, P>0.05, partial eta squared=0.01]. There was no significant main effect for session [Wilks Lambda=0.981, F(2, 27)=2.56, P>0.05, partial eta squared=0.19]. The main effect for ice cream was significant [F(1, 28)=4.53, P<0.05, partial eta squared=0.13]suggesting there was difference in EXCITED rating between the two ice creams, with participants in the Sainsbury's group being on average more excited than the Mackie's group (Please see DS table). However, pre meal excitement drops for the Sainsbury's group on the third session, but not at a statistically significant level, whereas pre meal excitement for the Mackie's is much more linear across the three sessions.

For TIRED rating there was a significant interaction between session and ice cream [Wilks Lambda=0.74, F(2, 27)=4.5, P<0.05, partial eta squared=2.53]. There was no significant main effect for session [Wilks Lambda=0.84, F(2, 27)=2.41, P>0.05, partial eta squared=0.15]. The main effect for ice cream was not significant [F(1, 28)=3.93, P>0.05, partial eta squared=0.13]suggesting there was not a difference in TIRED rating between the two ice creams.

For HAPPY rating there was not a significant interaction between session and ice cream [Wilks Lambda=0.96, F(2, 27)=0.54, P>0.05, partial eta squared=0.03]. There was no significant main effect for session [Wilks Lambda=0.96, F(2, 27)=0.51, P>0.05, partial eta squared=0.37]. The main effect for ice cream was not significant [F(1, 28)=0.09, P>0.05, partial eta squared=0.03]suggesting there was not a difference in HAPPY rating between the two ice creams.

For STRESSED rating there was not a significant interaction between session and ice cream [Wilks Lambda=0.98, F(2, 27)=0.19, P<0.05, partial eta squared=0.01]. There was no significant main effect for session [Wilks Lambda=0.98, F(2, 27)=0.20, P>0.05, partial eta squared=0.01]. The main effect for ice cream was not significant [F(1, 28)=0.22, P>0.05, partial eta squared=0.00]suggesting there was not a difference in STRESSED rating between the two ice creams.

For SAD rating there was not a significant interaction between session and ice cream [Wilks Lambda=0.89, F(2, 27)=1.5, P>0.05, partial eta squared=0.1]. There was no significant main effect for session [Wilks Lambda=0.94, F(2, 27)=0.84, P>0.05, partial eta squared=0.05]. The main effect for ice cream was not significant [F(1, 28)=0.01, P>0.05, partial eta squared=0.00]suggesting there was not a difference in SAD rating between the two ice creams.

For NERVOUS rating there was not a significant interaction between session and ice cream [Wilks Lambda=0.93, F(2, 27)=0.90, P>0.05, partial eta squared=0.06]. There was no significant main effect for session [Wilks Lambda=0.83, F(2, 27)=2.58, P>0.05, partial eta squared=0.16]. The main effect for ice cream was not significant [F(1, 28)=0.39, P>0.05, partial eta squared=0.01]suggesting there was not a difference in NERVOUS rating between the two ice creams.

For RELAXED rating there was not a significant interaction between session and ice cream [Wilks Lambda=0.97, F(2, 27)=0.30, P>0.05, partial eta squared=0.02].

There was no significant main effect for session [Wilks Lambda=0.84, F(2, 27)=2.4, P>0.05, partial eta squared=0.15]. The main effect for ice cream was not significant [F(1, 28)=0.69, P>0.05, partial eta squared=0.02]suggesting there was not a difference in RELAXED rating between the two ice creams.

Table 4.10 shows the descriptive statistics for mood ratings taken at the start of all three ice cream sessions.

Table 4.10: Pre session mood ratings (sessions1/2/3)

Ratings	Sainsbury's (Means & Standard Error) (Session1/2/3)	Mackie's (Means & Standard Error) (Session1/2/3)
BLOATED	20.7±5.9/27.6±7.2/14.5±5.2	24.8±5.7/23.4±7.0/23.5±6.3
EXCITED	56.2±3.9/58.5±6.4/51.2±5.8	41.4±5.8/41.9±6.9/41.3±7.9
TIRED	59.2±4.5/36.6±6.9/47.8±7.2	57.5±6.6/60.6±6.9/68.0±7.7
HAPPY	65.5±4.3/68±4.3/64.2±4.7	66.8±4.9/64.2±4.5/61.6±6.7
STRESSED	42.9±6.6/42.4±6.2/47.5±7.4	44±7.0/38.1±7.2/41.1±8.8
SAD	20.8±5.4/16.5±4.1/18.8±5.2	12.4±4.3/17.4±5.6/28.0±8.2
NERVOUS	23±5.5/11.8±4.3/18.5±5.6	18.8±4.9/15.2±5.2/30.1±8.6
RELAXED	66.2±3.6/63±5.7/51.9±5.8	59±5.6/56.8±6.5/52.0±6.7

Table 4.11 shows the descriptive statistics for mood ratings taken at the end of each of the three sessions.

Table 4.11: Post session mood ratings (session1/2/3)

Rating	Sainsbury's (Mean &Standard Error) (Session1/2/3)	Mackie's (Mean & Standard Error) (Session1/2/3)
BLOATED	45.1±6.4/42.8±8.9/37.9±7.0	42.1±7.7/40.5±8.7/36.5±8.0
EXCITED	41.7±6.9/47.5±6.6/46.5±6.6	25.2±6.5/41.4±7.5/37.0±7.3
TIRED	56.3±6.1/43.7±5.6/46.1±7.2	49.0±7.2/54.0±6.3/59.1±7.4
HAPPY	74.5±4.0/73.5±4.7/70.1±3.8	73.5±5.4/70.7±4.5/64.2±6.4
STRESSED	35.3±5.5/24.9±4.7/37.8±6.6	28.1±6.7/35.5±7.0/41.9±8.2
SAD	18.1±5.0/8.9±2.5/15.4±4.9	13.5±4.7/18.1±6.7/24.1±7.5
NERVOUS	10.6±3.6/9.6±3.1/15.9±4.7	10.2±4.4/12.3±4.5/18.7±7.5
RELAXED	71.8±4.6/77.5±3.0/71.3±4.0	76.0±4.1/70.1±4.9/58.3±7.8

No significant interactions or main effects were found except in any of the post meal ratings the case of RELAXED. For RELAXED rating there was a significant interaction between session and ice cream [Wilks Lambda=0.76, F(2, 27)=4.09, P<0.05, partial eta squared=0.23]. However there was no main effect for session [Wilks Lambda=0.83, F(2, 27)=2.6, P>0.05, partial eta squared=0.16]. The main effect for ice cream was not significant [F(1, 28)=1.04, P>0.05, partial eta squared=0.36] suggesting there was not a difference in RELAXED rating between the two ice creams.

4.2.3.2 Palatability ratings

Analysis of the palatability ratings took place using a mixed between within ANOVA design. Table 4.12 shows the mean palatability ratings between the ice creams.

Table 4.12: Palatability ratings across 3 sessions

Ratings	Sainsbury's (Mean & Standard error) (Session 1/2/3)	Mackie's (Mean & Standard error) (Session 1/2/3)
CREAMY	71.9±3.9/71.9±4.5/67.0±5.3	75.5±4.1/74.4±14.5/77.3±2.9
VISUALLY PLEASING	45.1±5.7/46.0±5.7/54.7±6.6	57.3±5.0/59.1±5.9/65.7±5.7
SWEET	68.7±4.1/75.1±3.8/74.6±3.2	66.5±5.4/73.6±3.9/74.3±4.0
PLEASANT	72.6±5.1/71.4±4.6/72.8±3.9	76.3±4.0/81.6±3.7/81.6±4.3
VANILLA FLAVOUR	55.9±4.8/58.3±5.6/61.9±4.9	68.6±4.1/71.8±3.6/66.5±4.9

No significant interactions or main effects were found in the palatability ratings. A more detailed analysis of the data is seen below.

For SWEET rating there was not a significant interaction between session and ice cream [Wilks Lambda=0.99, $F(2, 27)=0.11$, $P>0.05$, partial eta squared=0.00]. There was a significant main effect for session [Wilks Lambda=0.79, $F(2, 27)=3.4$, $P>0.05$, partial eta squared=0.20]. The main effect for ice cream was not significant [$F(1, 28)=0.06$, $P>0.05$, partial eta squared=0.02]suggesting there was not a difference in SWEET rating between the two ice creams.

For CREAMY rating there was not a significant interaction between session and ice cream [Wilks Lambda=0.90, $F(2, 27)=1.3$, $P>0.05$, partial eta squared=0.09]. There was not a significant main effect for session [Wilks Lambda=0.98, $F(2, 27)=0.14$, $P>0.05$, partial eta squared=0.01]. The main effect for ice cream was not significant [$F(1, 28)=1.13$, $P>0.05$, partial eta squared=0.03]suggesting there was not a difference in CREAMY rating between the two ice creams.

For VISUALLY PLEASING rating there was not a significant interaction between session and ice cream [Wilks Lambda=0.99, $F(2, 27)=0.03$, $P>0.05$, partial eta squared=0.00]. There was not a significant main effect for session [Wilks Lambda=0.81, $F(2, 27)=3.1$, $P>0.05$, partial eta squared=0.18]. The main effect for ice cream was not significant [$F(1, 28)=3.1$, $P>0.05$, partial eta squared=0.10] suggesting there was not a difference in VISUALLY PLEASING rating between the two ice creams.

For PLEASANT rating there was not a significant interaction between session and ice cream [Wilks Lambda=0.96, $F(2, 27)=0.50$, $P>0.05$, partial eta squared=0.03]. There was not a significant main effect for session [Wilks Lambda=0.96, $F(2, 27)=0.43$, $P>0.05$, partial eta squared=0.03]. The main effect for ice cream was not significant [$F(1, 28)=2.33$, $P>0.05$, partial eta squared=0.07] suggesting there was not a difference in PLEASANT rating between the two ice creams.

For VANILLA rating there was not a significant interaction between session and ice cream [Wilks Lambda=0.91, $F(2, 27)=1.23$, $P>0.05$, partial eta squared=0.08]. There was not a significant main effect for session [Wilks Lambda=0.96, $F(2, 27)=0.43$, $P>0.05$, partial eta squared=0.03]. The main effect for ice cream was not significant [$F(1, 28)=3.45$, $P>0.05$, partial eta squared=0.11] suggesting there was not a difference in VANILLA rating between the two ice creams. Below are two graphs showing the within meal descriptive statistics for Sainsbury's and Mackie's across the three session.

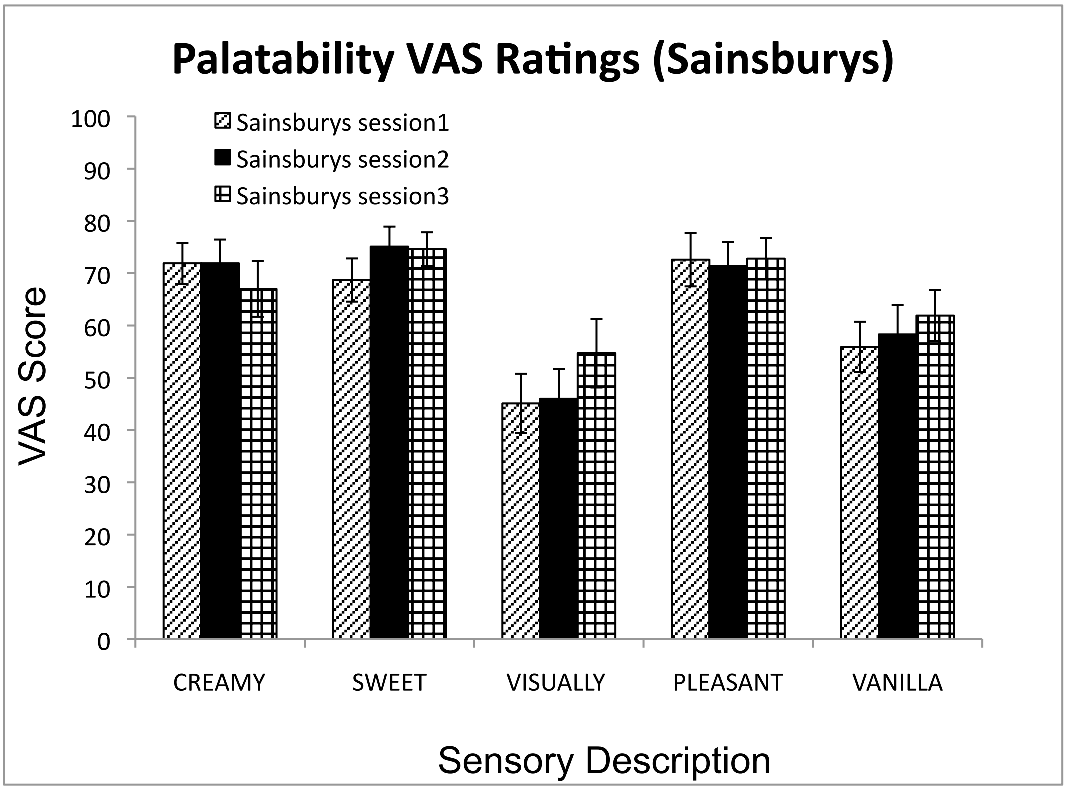


Figure 4.8: Palatability VAS ratings across 3 sessions Sainsbury's

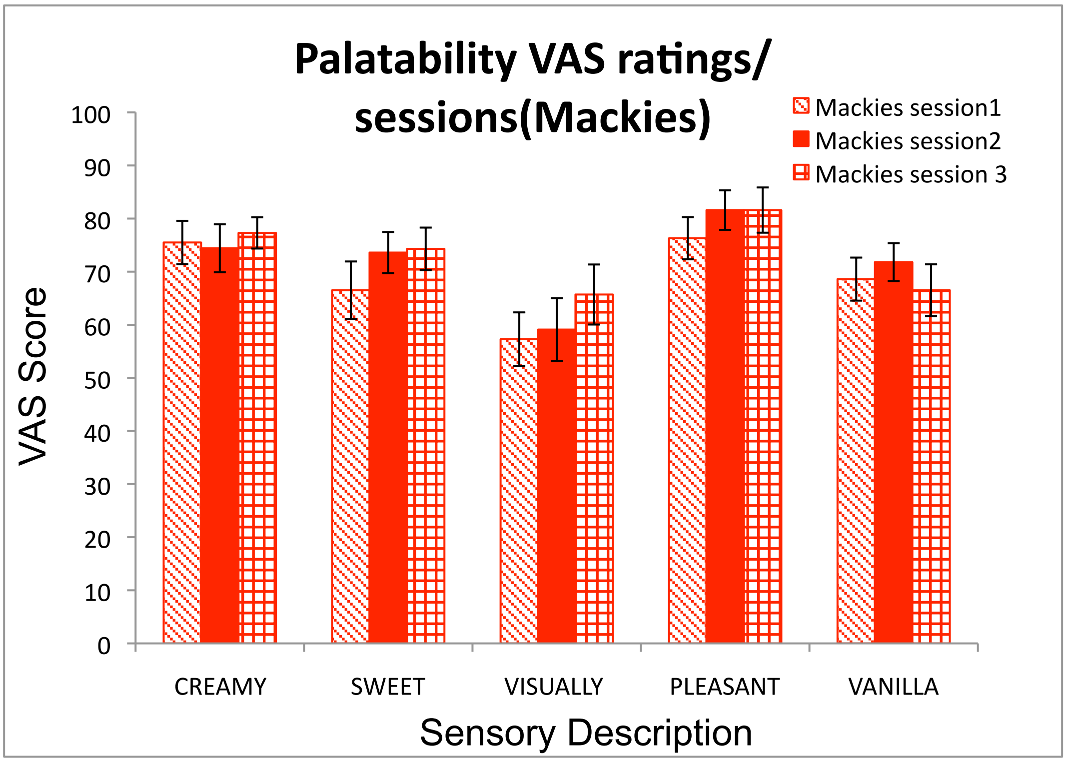


Figure 4.9: Palatability VAS ratings across 3 sessions Mackie's

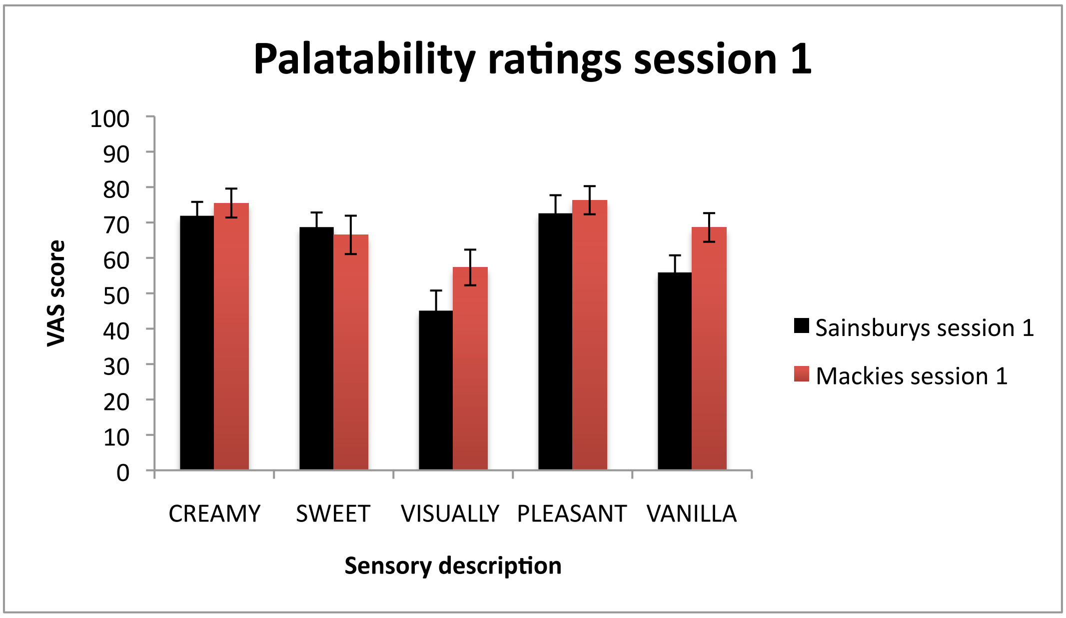


Figure 4.10: Palatability VAS ratings session 1

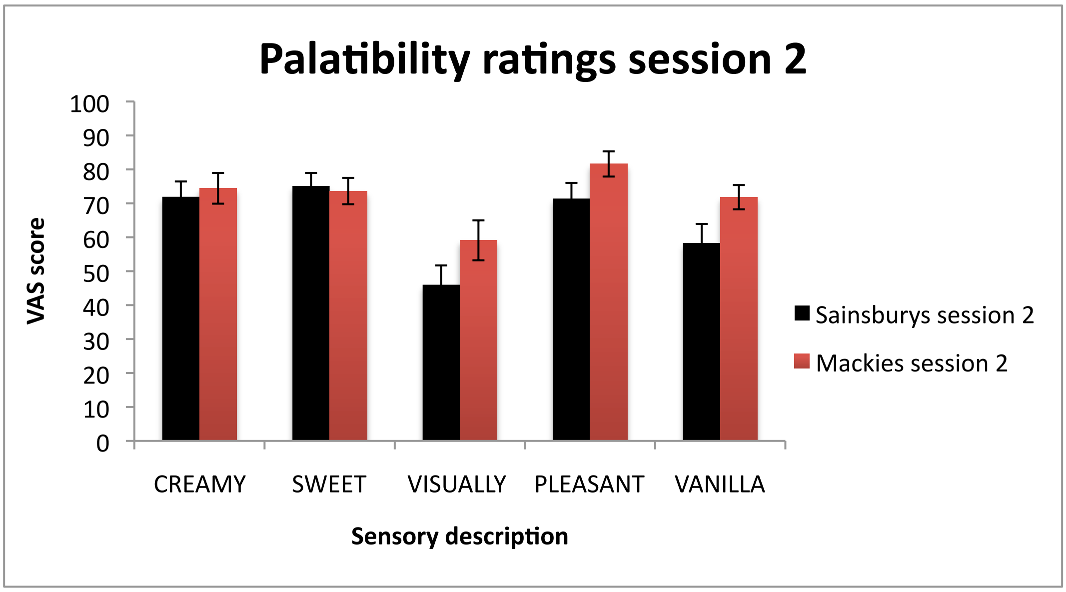


Figure 4.11: Palatability VAS ratings session 2

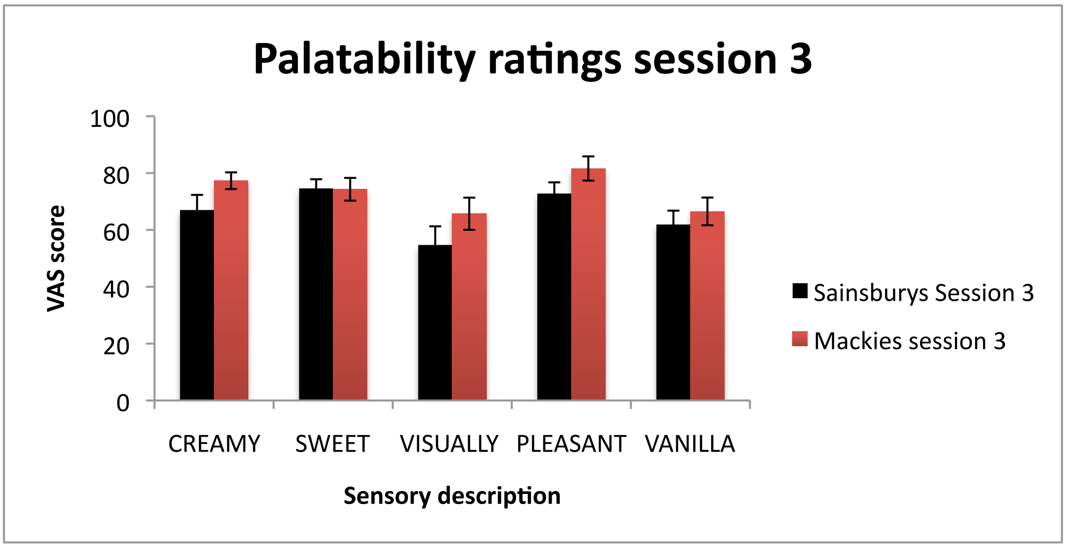


Figure 4.12: Palatability VAS ratings session 3

There was also no significant interaction or main effects for session or ice cream when examining 'Likelihood to purchase' rating. [Wilks Lambda=0.94, F(2, 27)=0.47, P>0.05, partial eta squared=0.03]

4.2.3.3 Overall Food Intake and rate of intake

Overall average mass consumed between the ice creams showed no interaction between session and ice cream [Wilks Lambda=0.90, F(2, 27)=1.35, P>0.05, partial eta squared=0.09] with no main effect of session [Wilks Lambda=0.87, F(2, 27)=1.9, P>0.05, partial eta squared=0.12] and no main effect of ice cream [F(1, 28)=0.290, P>0.05, partial eta squared=0.01] with participants consuming similar mean gram amounts of both ice creams over the three sessions, which can be seen in the table below.

Table 4.13: Average amount of ice cream consumed over 3 sessions

Session	Sainsbury's (Means & Standard Error)	Mackie's (Means & Standard Error)
1	100±14.2	117±15.6
2	100±13.4	118±17.0
3	125±15.0	122±15.4

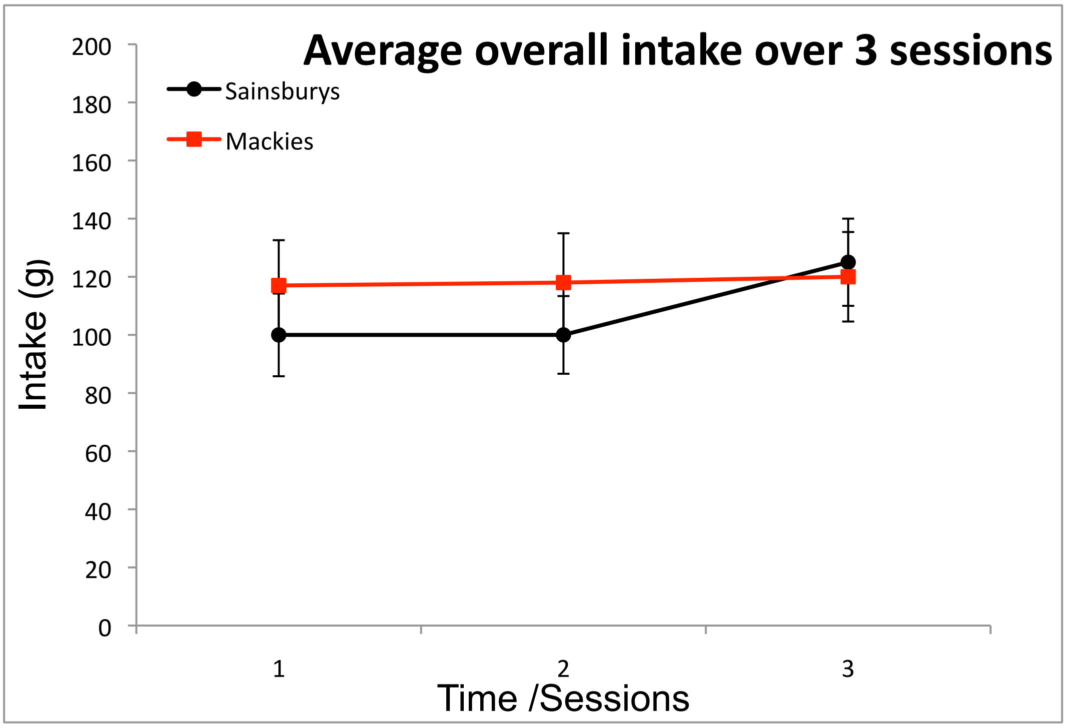


Figure 4.13: Average overall intake for 3 sessions

There was again very little difference in the total average grams eaten between the three sessions, with participants peaking on the third and final session. This peaking on the third session was also witnessed with the lower quality ice cream with participants eating slightly more on the third session (18-25grams) compared to sessions one and two, however, this result was not at a significant level.

Overall intake when expressed as energy density (ED) showed that there was no significant interaction between session and ice cream [Wilks Lambda=0.94, $F(2, 27)=0.78$, $P>0.05$, partial eta squared=0.05]. The main effect of session showed no significant effect on ED consumption [Wilks Lambda=0.941 $F(2, 27)=1.2$, $P>0.05$, partial eta squared=0.08]. The main effect of comparing the two ice cream groups was significant [$F(1,28)=8.1$, $P<0.05$, partial eta squared=0.22] showing that there was a difference in ED consumption between the ice creams. Below is a table showing the descriptive statistics for ED.

Table 4.14: Energy density consumed over 3 sessions

Session	Sainsbury's (Means & Standard Error)	Mackie's (Means & Standard Error)
1	569.5±80.3	1007.6±133.3
2	564.9±75.4	1010.6±145.1
3	708.1±84.7	1029.9±131.7

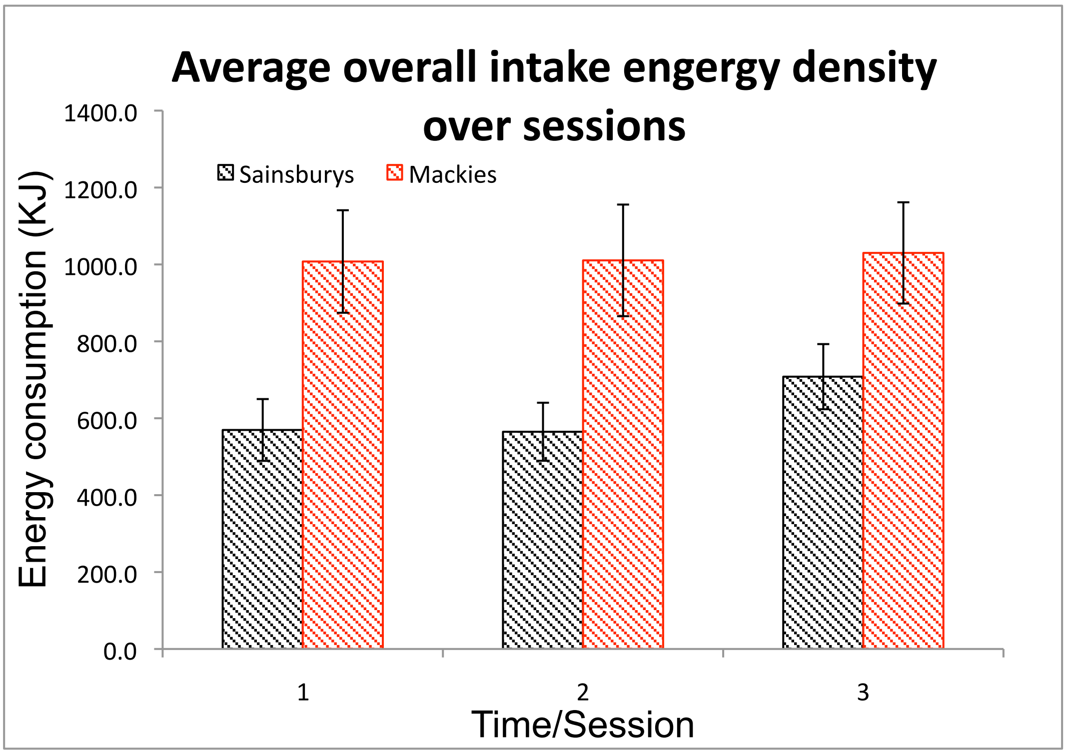


Figure 4.14: Average ED over three sessions

Rate of intake is indicated in below. Difference in rate of intake was measured minute against minute within each session between the ice creams. Table 4.15 shows the descriptive statistics for the rate of intake between the ice creams.

Table 4.15: Rate of intake over 3 sessions

Minute	Sainsbury's (Means & Standard Error) (Session1/2/3)	Mackie's (Means & Standard Error) (Session1/2/3)
1	20.4±4.0/25.3±4.7/21.4±2.8	13.0±1.5/13.4±2.5/19.3±5.9
2	41.6±5.8/45.7±4.0/46.1±6.4	35.0±4.5/31.9±5.3/33.4±6.8
3	57.1±6.5/64.2±3.2/68.6±6.0	55.3±5.5/52.8±7.3/53.2±8.4
4	71.2±8.6/76.5±4.5/87.6±7.6	74.3±8.6/65.1±7.8/72.6±9.4
5	82.0±10.6/86.1±8.0/102.0±10.25	89.9±10.8/80.1±9.7/85.0±9.4
6	89.2±11.7/91.9±10.3/113.9±12.0	102.7±12.8/92.9±12.0/95.7±10.3
7	96.8±13.5/94.9±11.2/123.3±14.52	109.8±13.7/104.1±14.1/105.2±11.7
8	99.7±14.0/97.9±12.38/124.9±14.8	112.2±14.2/110.2±15.4/111.9±13.3
9	100.8±14.2/99.3±12.9/125.3±15.0	115.0±14.9/113.0±15.8/117.1±14.5
10	100.8±14.2/100.0±13.3/125.3±15.0	116.1±15.1/115.4±16.3/119.1±15.0
11	100.8±14.2/100.0±13.3/125.3±15.0	117.3±15.4/117.0±16.6/120.5±15.4
12	100.8±14.2/100.0±13.3/125.3±15.0	117.9±15.6/118.2±17.0/120.5±15.4

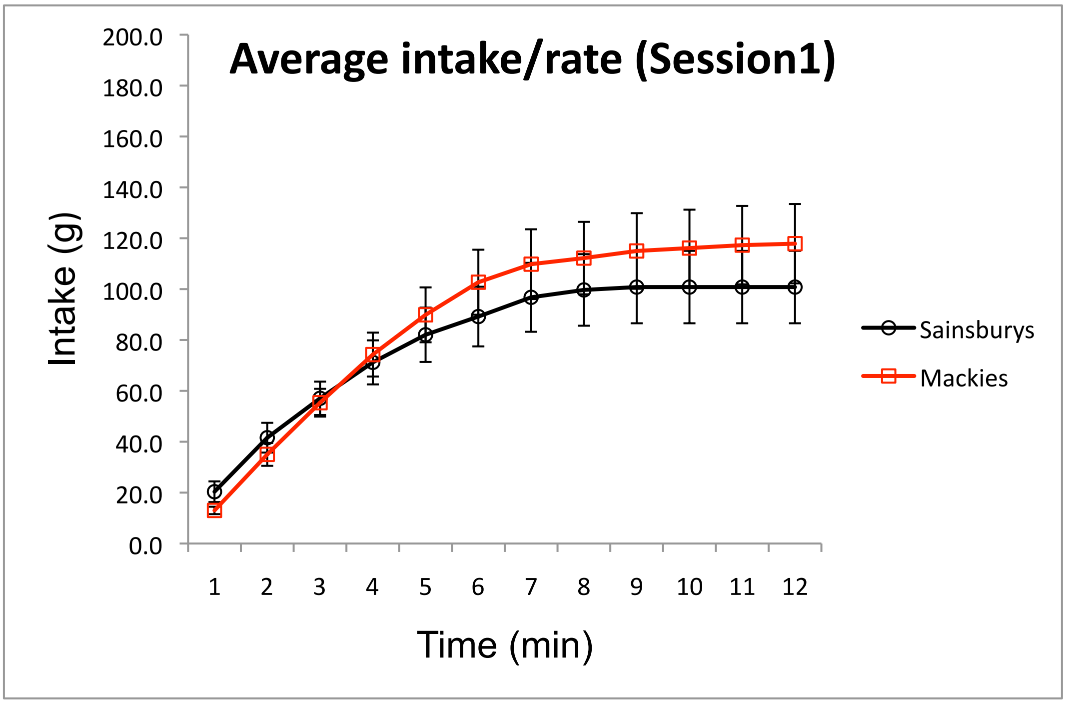


Figure 4.15: Rate of intake session 1

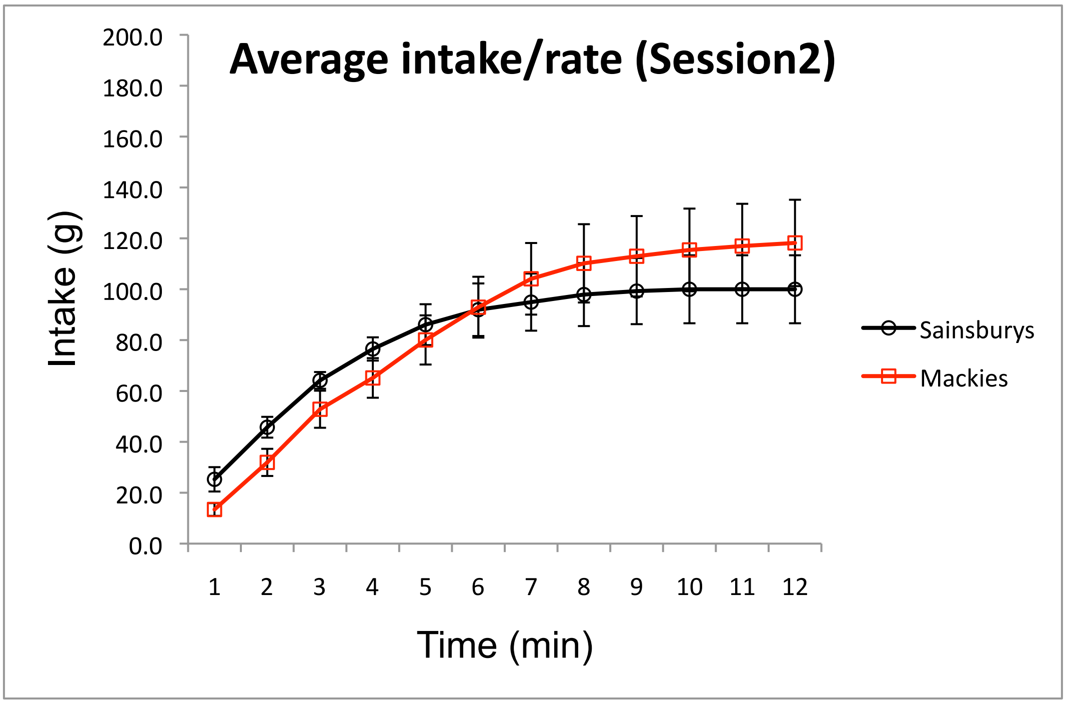


Figure 4.16: Rate of intake session 2

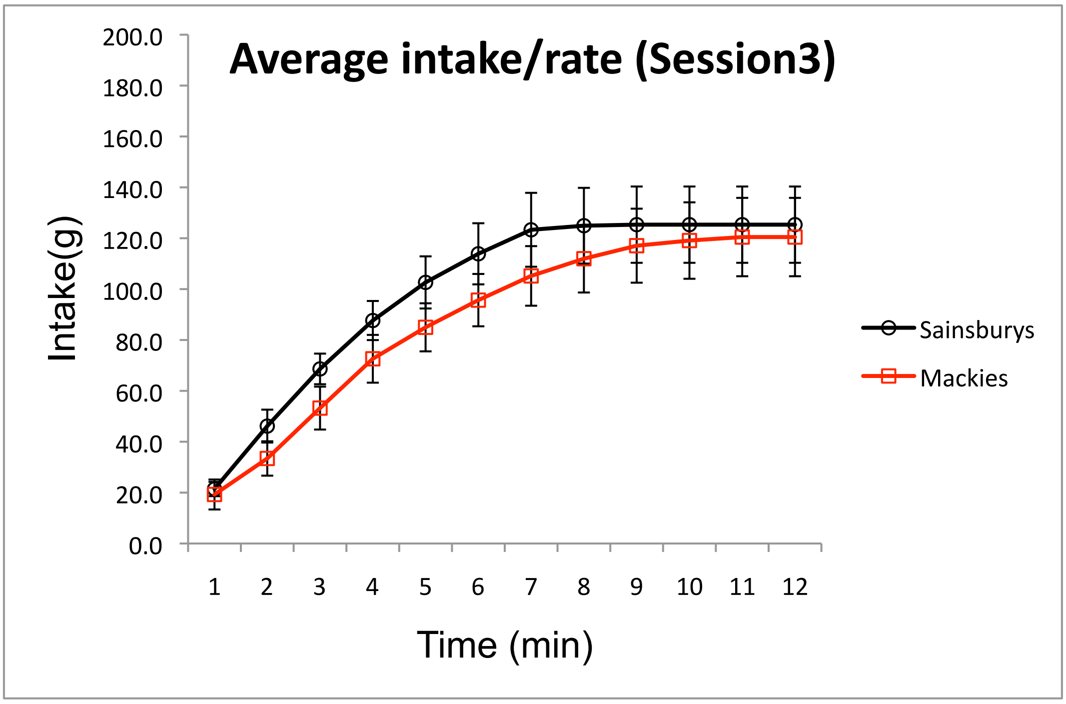


Figure 4.17: Rate of intake session 3

In order to assess whether there is a difference between rates of intake between two ice creams across three sessions, three way mixed between-within ANOVAs was conducted comparing ice cream intake minute vs. minute within the sessions. Independent variable of ice cream had two levels (high/low quality), independent variable of time had 11 levels (minutes) and independent variable of session had three levels. The dependent variable was grams eaten per minute. Results from the Multivariate test box showed that there was no significant interaction for session and ice cream (Wilks Lambda=0.918, $F(2,27)=1.2$, $p>0.05$, partial eta squared=0.82], minute and ice cream [Wilks Lambda=0.754, $F(11,18)=0.53$, $p>0.05$, partial eta squared=0.82], or session and minute [Wilks Lambda=0.401, $F(21,8)=0.57$ $P>0.05$, partial eta squared=0.64]. There was also no main effect for sessions [Wilks Lambda=0.882, $F(2,27)=1.8$, $P>0.05$, partial eta squared=0.11] or ice cream [$F(1,28)=0.00$, $P>0.05$, partial eta squared=0.00].

4.2.3.4 Changes in within meal appetite

Table 4.16 shows the means and standard errors for pre meal ratings.

Table 4.16: Pre session enjoyment/hunger/fullness VAS ratings

RATINGS	Sainsbury's (Means & Standard Error) (Session1/2/3)	Mackie's (Means &Standard Error) (Session1/2/3)
ENJOYMENT	71.5±4.4/67.7±5.3/78.9±3.3	79.3±5.1/78.8±4.9/78.6±3.5
HUNGER	53.3±4.4/47.9±7.5/68.5±4.1	48.8±6.0/45.8±6.6/42.2±7.3
FULLNESS	38.3±5.0/43.6±6.7/24.8±4.4	37.7±5.6/41.1±5.7/45.6±6.7

A mixed between ANOVA was carried out on each of the pre meal ratings.

Results indicated that for pre meal ENJOYMENT ratings there was no interaction between session and ice cream [Wilks Lambda=0.88, F(2, 27)=1.7, P>0.05, partial eta squared=0.1] along with no main effect for session [Wilks Lambda=0.89, F(2, 27)=1.5, P>0.05, partial eta squared=0.1] or ice cream [F(1, 28)=1.6, P>0.05, partial eta squared=0.0].

For pre meal HUNGER ratings, results indicated that was no interaction between session and ice cream [Wilks Lambda=0.82 F(2, 27)=2.9, P>0.05, partial eta squared=0.1] along with no main effect for session [Wilks Lambda=0.91, F(2, 27)=1.2, P>0.05, partial eta squared=0.0] but that there was a significant effect or ice cream [F(1, 28)=4.3, P<0.05, partial eta squared=0.1] meaning that there was a significant difference in the pre meal hunger ratings for the two ice cream groups. A closer look at the means for the third session pre meal hunger ratings show VAS ratings of Sainsbury's (M=68.5) and Mackie's (M=42.2), indicating that

Sainsbury's participants were more hungry than their Mackie's counterparts, and whilst they did consume more of the Sainsbury's ice cream on the third session, this was not at a significant level (please see previous pages).

For pre meal FULLNESS ratings, results showed no interaction between session and ice cream [Wilks Lambda=0.86, F(2, 27)=2.1, P>0.05, partial eta squared=0.1] and no main effect of session [Wilks Lambda=0.94, F(2,27)=0.79, P>0.05, partial eta squared=0.0] and no main effect for ice cream [F(1,28)=1.4, P>0.05, partial eta squared=0.0].

A three way mixed ANOVA was then carried out to compare the within subject variables of session and quartiles with the between subject variables of ice cream on ENJOYMENT VAS scores.

Descriptive statistics for ENJOYMENT can be seen in the table below.

Table 4.17: Descriptive statistics for enjoyment VAS scores over quartiles

Session	Quartiles	Sainsbury's	Mackie's
1	1	70.3±4.0	79.1±5.9
	2	68.4±4.5	73.4±6.1
	3	67.5±4.7	70.2±6.8
	4	68.3±5.1	67.5±7.5
2	1	67.7±5.6	72.9±5.3
	2	66.5±5.4	71.3±5.0
	3	65.9±5.8	70.6±5.4
	4	63.9±6.2	71.4±5.9
3	1	78.8±3.1	81.5±4.0
	2	76.4±3.6	79.4±4.6
	3	74.3±4.0	74.4±5.1
	4	73.7±4.0	75.0±5.1

Results indicate that there is no interaction between session and ice cream [Wilks Lambda=0.98, $F(2, 27)=0.26$, $P>0.05$, partial eta squared=0.01] on enjoyment scores, but that there is a main effect for session [Wilks lambda=0.76, $F(2,27)=4.1$, $P<0.05$, partial eta squared 0.23] with both ice creams showing a difference in enjoyment scores across the three sessions. There is no interaction between quartile and ice cream [Wilks Lambda=0.96, $F(3, 26)=0.27$, $P>0.05$, partial eta squared=0.3] and no main effect for quartile [Wilks Lambda=0.84, $F(3,26)=1.5$, $P>0.05$, partial eta squared 0.1] indicating that enjoyment scores did not differ significantly across the quartiles between the ice creams. There was also no interaction between session and quartile [Wilks Lambda=0.84, $F(6, 23)=0.68$, P>0.05, partial eta squared=0.1], and no main effect for quartile [Wilks Lambda=0.84, F(3,26)=1.5, P>0.05, partial eta squared 0.1]. There was also no main effect for ice cream on enjoyment scores [F(1,28)=0.41, P>0.05, partial eta squared=0.1]. Below is a graph displaying the within meal enjoyment scores across the three sessions. Closer inspection of the graph and the means of the enjoyment scores indicate that enjoyment was higher for both ice creams on the third session.

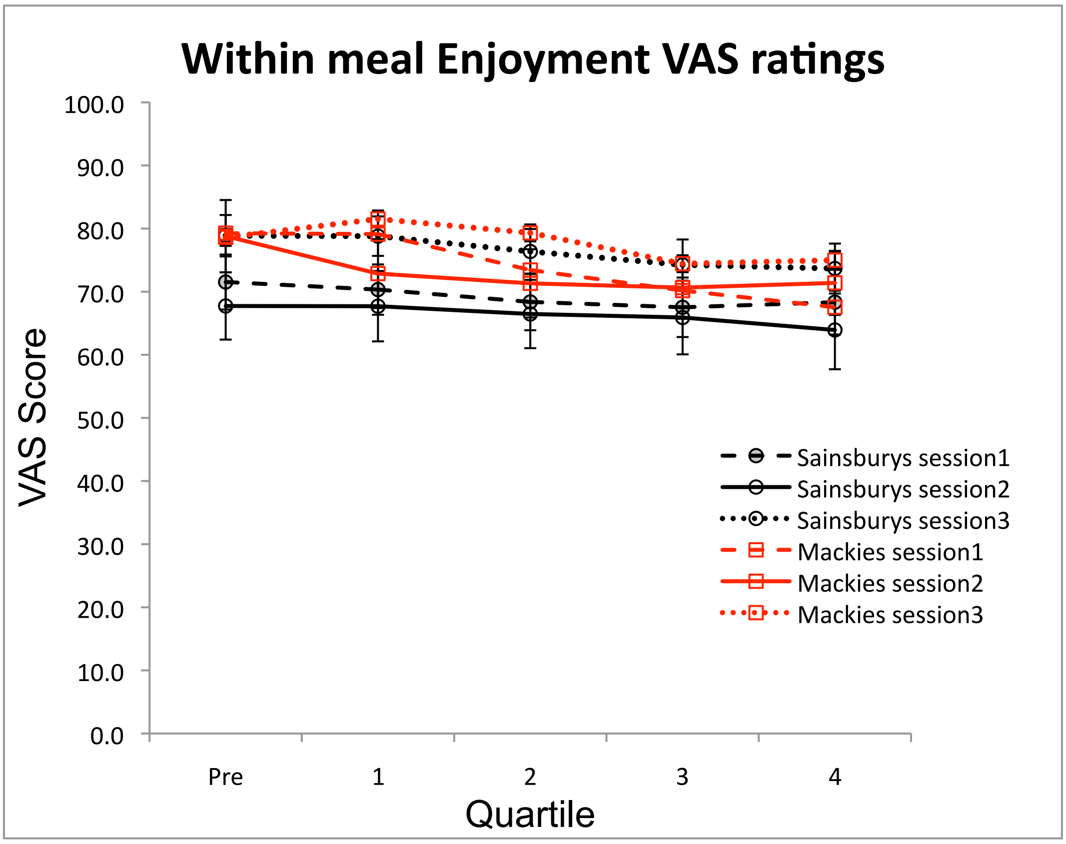


Figure 4.18: Within meal enjoyment VAS ratings over quartiles

A three way mixed ANOVA was then carried out to compare the within subject variables of session and quartiles with the between subject variables of ice cream on HUNGER VAS scores.

Descriptive statistics for HUNGER can be seen in the table below.

Table 4.18: Descriptive statistics for hunger VAS ratings over quartiles

Session	Quartiles	Sainsbury's	Mackie's
1	1	42.2±3.8	41.4±5.5
	2	32.8±3.9	32.0±5.5
	3	26.0±4.5	25.5±5.1
	4	15.4±3.7	18.5±5.7
2	1	44.2±7.2	39.3±5.4
	2	40.1±7.0	32.5±5.5
	3	35.4±7.0	23.8±4.5
	4	28.0±6.8	14.9±4.1
3	1	57.3±4.1	42.2±5.9
	2	55.5±6.5	36.7±5.4
	3	51.6±7.1	30.3±4.8
	4	40.1±7.1	23.8±4.6

Results indicate that there is no interaction between session and ice cream [Wilks Lambda=0.87, $F(2, 27)=1.9$, $P>0.05$, partial eta squared=0.1] on hunger scores, but that there is a main effect for session [Wilks lambda=0.74, $F(2,27)=4.7$, $P<0.05$, partial eta squared 0.2] with both ice creams showing a difference in hunger scores across the three sessions. There is no interaction between quartile and ice cream [Wilks Lambda=0.87, $F(3, 26)=1.2$, $P>0.05$, partial eta squared=0.1] but there is a significant effect for quartile [Wilks Lambda=0.30, $F(3,26)=19.9$, $P<0.05$, partial eta squared 0.6] indicating that hunger scores differed significantly across the quartiles between the ice creams, which is to be expected, as more grams eaten, hunger scores decreased. There was also no interaction between session and quartile [Wilks Lambda=0.80, $F(6, 23)=0.91$, $P>0.05$, partial eta squared=0.1]. There was also no main effect for ice cream on hunger scores [$F(1,28)=3.2$, $P>0.05$, partial eta squared=0.1]

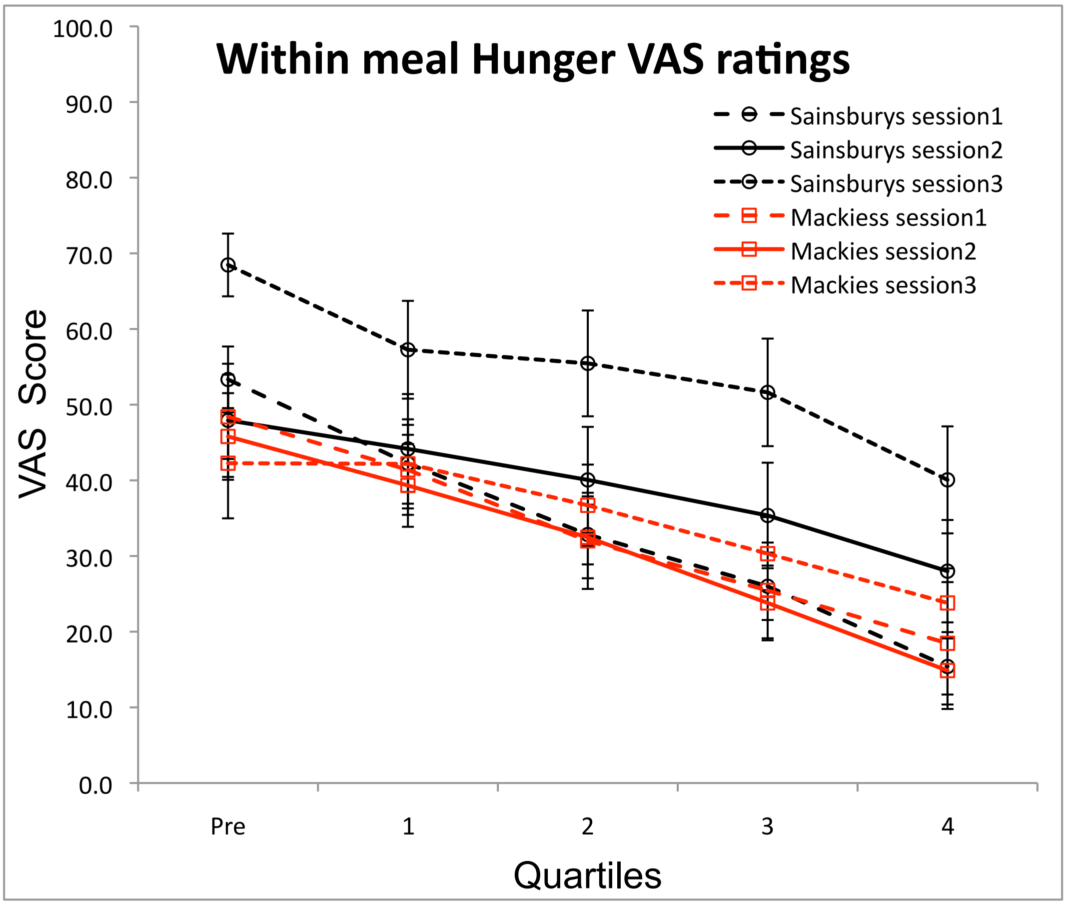


Figure 4.19: Within meal hunger VAS ratings over quartiles

A three way mixed anova was then carried out to compare the within subject variables of session and quartiles with the between subject variables of ice cream on FULLNESS VAS scores.

Descriptive statistics for FULLNESS can be seen in the table below.

Table 4.19: Descriptive statistics for fullness over quartiles

Session	Quartiles	Sainsbury's	Mackie's
1	1	47.6±3.4	45.5±5.9
	2	60.6±3.3	56.1±6.4
	3	69.3±3.7	64.4±6.3
	4	75.7±3.7	67.0±8.1
2	1	49.3±6.7	46.7±5.5
	2	53.6±6.7	55.8±5.4
	3	61.4±6.5	62.4±4.9
	4	69.2±6.4	72.8±5.1
3	1	31.8±5.3	50.8±6.1
	2	42.9±6.5	59.5±5.5
	3	52.0±6.7	65.4±5.1
	4	61.2±6.5	76.0±4.6

Results indicate that there is no interaction between session and ice cream [Wilks Lambda=0.84, $F(2, 27)=2.4$, $P>0.05$, partial eta squared=0.1] on fullness scores, and no significant main effect for session [Wilks lambda=0.94, $F(2,27)=0.75$, $P>0.05$, partial eta squared 0.5] meaning that fullness scores did not differ significantly across the sessions. There is no interaction between quartile and ice cream [Wilks Lambda=0.94, $F(3, 26)=0.47$, $P>0.05$, partial eta squared=0.05] and a significant difference in the main effect for quartile [Wilks Lambda=0.14 $F(3,26)=50.1$, $P<0.05$, partial eta squared 0.8] indicating that fullness scores differed significantly across the quartiles between the ice creams, which is to be expected, as more grams eaten, fullness scores increased. There was also no interaction between session and quartile [Wilks Lambda=0.79, F(6, 23)=1.0, P>0.05, partial eta squared=0.2]. There was also no main effect for ice cream on fullness scores [F(1,28)=0.47, P>0.05, partial eta squared=0.1]

Below is a graph showing within meal fullness ratings.

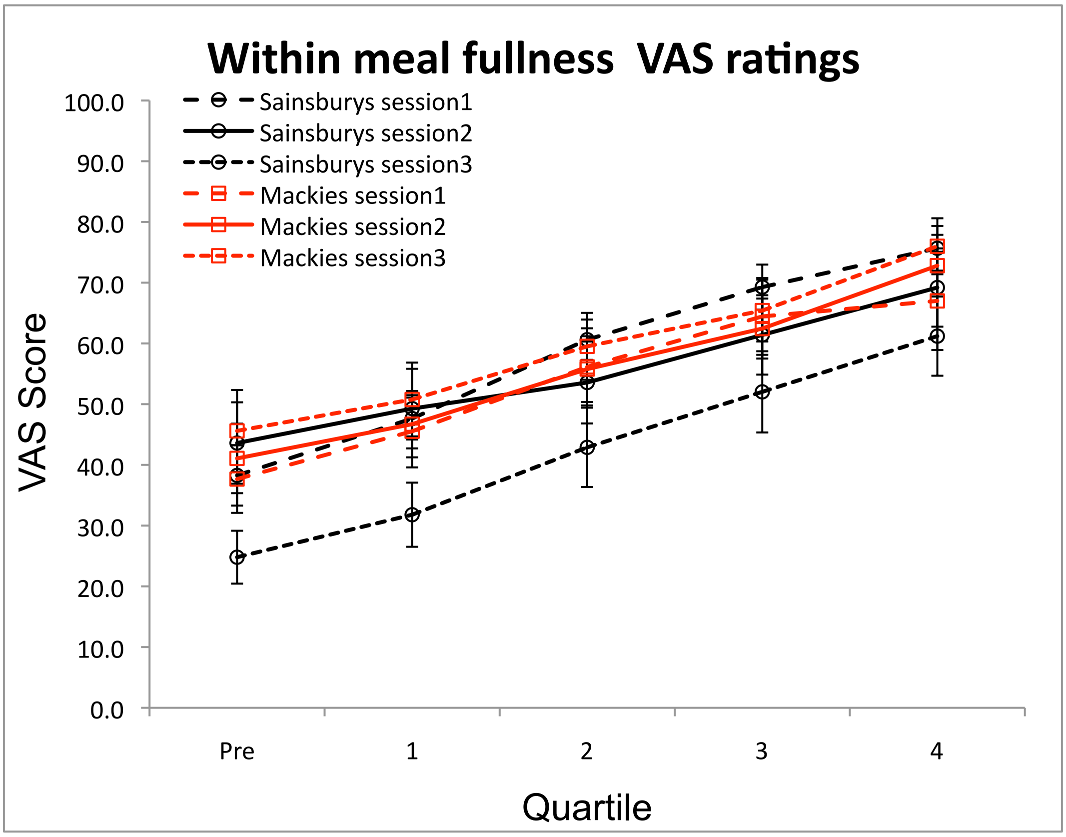


Figure 4.20: Within meal fullness VAS ratings over quartiles

4.2.4 Discussion

The results suggest that from a consumer's perspective there is very little that separates the ostensibly very different ice cream formulations based on oral properties (taste and mouth feel). Also that these assessments of consumers are not modified by learning over three days. Yeomans (2008) found that enhanced liking for flavours through flavour-based learning should increase intake. Other investigations into the appetizer effect and learned behaviour found that this was not the case for this study. However, this could have been due to the participants only being tested over three days, and learning may occur through prolonged exposure.

Investigations indicate that increased eating rate is associated with increased intake, and that more palatable foods should also increase intake. Previous studies have shown that with pasta for example, increasing the palatability of a sauce leads to increased consumption of the meal (Yeomans, 2008), and that often, there is a direct correlation between palatability and the energy density of the food, with the higher energy dense foods lending themselves to be more palatable (Drewnowski, 1998). However, this was not the case in this instance, as there was no significant difference in the total intake or rate of intake between the two ice creams. This may be due to the fact that ice cream is often seen as an indulgent food, and therefore consumers will continue to eat even a poorly formulated product, due to a predisposition for liking to the food. It may also be the case that with ice cream, consumers rely more heavily on packaging and labelling to make an informed choice. The little difference found between the total intake and rate of intake between the ice creams may also be related to the findings of Willemijn (2009) who stated that consumers often find self-regulation of large portions difficult at the moment of consumption. The eating rate of ice cream is complex due to multiple food properties being involved, and the fact that it is a highly processed food. It would have been expected that the higher fat ice cream would have a higher eating rate due to not only the fact it was chosen as it was more palatable but also due to the fat content, as fat provides oral properties such as creaminess and softness, enabling quicker passage through the oral cavity. Physical measurements such as tribology and rheology, discussed in Chapter 5, were able to show the difference between the fat properties of the ice cream.

4.3 Additional triangle tests in which commercially available ice creams are manipulated through the process of temperature cycling to alter ice crystal size

Following the results gained from the two investigations into commercially available ice creams, the decision to examine the effects of manipulating these ice creams on sensory and palatability was taken. This came in the form of temperature manipulation through temperature abuse. Initially, through information gained through research into temperature abuse (Clarke, 2008) and food, it was considered that temperature abuse would take place through means of temperature cycling from frozen to unfrozen back to frozen as this would best alter the ice crystal structure of the ice creams, therefore leading to more obvious sensory alterations being detected. This also replicates the very real consumer issue of buying ice cream in the real world and transporting it home. However, due to food safety issues surrounding bacteria growth and possible contamination, it was decided that whilst this may be fine for conducting engineering based measurements into the ice creams, this would not be safe for human participants to ingest, and therefore no accurate sensory/palatability measurements could be gained. Therefore, the temperature abuse would take place through super freezing cycling, moving the ice creams between regular household freezers of -18°c to a low temperature freezer of -80°c for the period of a week. A triangle test was carried out to determine whether participants could tell which sample was different from the other two. This is a discriminatory style design used within sensory science to try and gauge if an overall difference is present between products

Hypothesis

H1: Participants will successfully be able to indicate which one ice cream is different to the other two ice creams.

4.3.1 Methodology

4.3.1.1 Participants

A total of 30 participants (all female, all students) were selected from Birmingham University. An advert was placed on the University of Birmingham online participation scheme where students could sign up to the study. Please see Chapter 4 appendix for advert. Restricted eaters and males were once again excluded. Participants that took part in the previous ice cream studies were also excluded from this study. Smokers and people with food allergies were also excluded. Participants were randomly allocated into high quality/low quality groups and remained in that group, and were not aware of which group they had been placed in.

4.3.1.2 Ice creams

The ice creams remained the same as in the previous studies; however, batches of both ice creams had been structurally manipulated through temperature abuse. For one week, the ice creams were moved between an -18°c freezer and an -80°c freezer every 24hrs (apart from at the weekend when they remained in the -80°c freezer). Therefore sample consisted of ‘normal’ ice creams (ice creams normally stored at home freezer temperature, and the temperature-abused ice creams.

4.3.1.3 Design and procedure

A triangle test design was employed for this study. This is a discriminatory style design used within sensory science to try and gauge if an overall difference is present between products and determining whether shifts in processing for ingredients have significantly altered the sensory qualities of the product. In this case, the purpose is to test the limit of sensitivity to ice crystal deformation in the ice cream samples.

Participants arrived at testing room and were asked to read a volunteer information sheet and asked to read and sign a consent form. They were then taken into a small room and asked to sit down whilst the samples were prepared. Samples were prepared in the test kitchen, and each of the three ice cream samples were presented in identical containers and coded using 3 digit codes (754/341/427), following a balanced experimental test design, and the order of the ice cream placement was randomised. The participant was then presented with three samples (two are the same and one is different) and asked to evaluate the samples from left to right, select the "different" sample and describe the difference perceived. Participants were instructed to use palate cleansers of water and plain crackers to clean the palate between samples to minimise flavour carry–over. The participant was asked to select a sample even if they believed there was no difference between the samples. The participants were asked to state if their answer was a guess in the comments section, which is standard practice.

This procedure was followed for both high quality and low quality ice creams, with 15 participants being allocated into each group.

The number of correct answers were then counted and compared to verify whether it could be concluded that a statistically significant difference exists between the two samples. Please see Chapter 4 appendix for example of triangle test given to participants and consent form and volunteer information sheet.

4.3.2 Results and discussion

A chi-squared distribution was carried out to assess whether participants were able to determine which ice cream sample was different to the other two.

Table 4.20: Triangle test results

Ice cream	Number of participants	No. Correctly identified different sample	Significance
Sainsbury's	15	13	0.05
Mackie's	15	9	0.43

Table 4. 21 Descriptors used by participants when sample was correctly identified as being different.

Table 4.21: List of descriptors used by participants

Ice cream	
Sainsbury's (normal sample)	Vanilla flavour (2) Vanilla smell (1) Guess (2)
Sainsbury's (temperature abused sample)	Orangey type flavour (2) Gritty/rough/icy (5) Guess (1)
Mackie's (normal sample)	Creamy (2) Vanilla flavour (3)
Mackie's (temperature abused sample)	Rough/gritty (2) Guess (2)

From the results above, it seems clear that participants in the Sainsbury's group were significantly able to indicate which ice cream was different to the other two, but the participants in the Mackie's group were not. More participants (5) in the Sainsbury's group also indicated a 'gritty/rough/icy' texture to the temperature-abused ice cream when compared to the Mackie's group (2). When temperature abusing ice cream above 0°c, it is expected ice crystals to become larger in size, leading a gritty mouth feel, however, as temperature abuse occurred between -80°c and -18°c, this indicates that in the lower quality ice cream this was picked up on by participants, more so than in the higher quality ice cream. Another interesting and unexpected result was the description of an 'orangey flavour' with the temperature abused Sainsbury's ice cream. Two different participants indicated this. There is evidence to suggest that food products, particularly dairy products can ‘pick up’ other flavours around which they are stored (Goff, 2009) however, all the samples were sealed and not opened until sampling.

There are limitations to the triangle test, which may have impacted on the test. Triangle tests only give indication of a difference, not the direction of the difference, nature of the difference or the size of the difference. This is why the descriptive are so important when looking at the results. The results gathered in this chapter certainly were not as expected, and further physical engineering measurements of the ice creams, both high and low quality, temperature abused and non-temperatures abused were carried out.

CHAPTER 5: ENGINEERING INVESTIGATIONS

The following section will describe the materials and methods used to develop understanding and analysis of commercially available ice creams used in the previous chapters, which is achieved through a range of different laboratory based tests. All samples were stored in a -20°c Beko chest freezer prior to analysis and some samples were cycled between a -80°c and -20°c food grade freezer. These samples will be differentiated as ‘cycled’ samples. The commercial ice creams were split into two groups, high (Mackie’s) and low (Sainsbury’s) quality -20°c samples, referred to as normal samples, and high and low quality -80°c cycled samples, referred to as cycled samples.

As results from the triangle test in Chapter 4 showed there was a very definitive sensory difference between -80°c cycled sampled of ice creams, these samples were incorporated into laboratory analysis where it could be accommodated.

Following the methods outlined in this section should enable a complete formulative and comparative study of high and low quality commercially available ice creams used in previous sensory experiments in Chapter 4. The ultimate goal of these laboratory-based experiments was to compare engineering based results with results gathered from human participants, so an overall picture of ice cream formulation and its sensory interpretation by the consumer could be better understood.

5.1 Material and methods

5.1.1 Ingredients and nutritional information for commercial ice creams

Mackie's of Scotland Traditional Luxury Dairy Ice cream (High quality)

- Fresh Whole Milk, Double Cream (16%),
- Sugar
- Skimmed Milk Powder
- Glycerine
- Eggs
- Emulsifier (Mono- and Diglycerides of Fatty Acids)
- Stabilisers (Sodium Alginate and Guar Gum).
- Contains No Artificial Flavours, Colours or Preservatives.

Sainsbury's Basic Vanilla Ice Cream (Low quality)

- Partially Reconstituted Lactose Reduce Whey Powder (From Cows' Milk)
- Sugar
- Vegetable Oil
- Glucose Syrup
- Emulsifier (Mono-and Diglycerides of Fatty Acids)
- Stabilisers (Guar Gum, Sodium Alginate)
- Flavouring
- Colours (Curcumin, Annatto

Table 5.1: Composition of ice creams

	Mackie's (High quality) 100g	Sainsbury's (Low quality) 100g
Price	29.7p	4.5p
Energy kcal	204kCal	134kCal
Energy kJ	855kJ	565kJ
Protein	3.6g	2.5g
Carbohydrate	23.2g	19.7g
of which sugars	N/A	17.5g
Fat	10.8g	5.1g
of which saturates	N/A	3.2g

5.1.2 Slumping

Slumping/Stand up and meltdown tests were performed in order to analyse the ice creams behaviour under the influence of gravity at different temperatures (-20°c normal samples). The temperatures investigated for the commercial samples were 25°c and 37°c. Pictures were taken at 5 minutes and 30 minutes and taken with an iphone 4 camera but measurements (height in cm) were taken every 5 minutes for 30 minutes. The camera was capable of taking pictures at a resolution of 8 mega pixels.

The ice creams were cut into blocks and left in the freezer over night. They were then weighed (100g) and placed in a Perspex box with a scale. For the 25°c samples, the ice cream blocks were left at room temperatures and photographs were taken at the time intervals indicated above. For the 37°c samples, an incubator was used. The relative loss of visible sample was expressed as cm squared.

5.1.3 Rheology measurements

Viscometery tests on the commercial ice creams both normal and cycled samples were performed on a Bohlin HR Nano 150 Rheometer from Malvern Instruments (Malvern, Worcestershire, UK). Gap loading was between 2mm and 1mm dependent on sample thickness and the temperature of each of the test runs was 37°c. The sample viscosity was tested as a function of shear stress. The samples were tested shear stresses from 1 to 1000Pa.

5.1.4 Tribology measurements

In order to mimic in mouth conditions, a mini traction machine developed by PCS Instruments (London, UK) was used at 37°c. A Stribeck curve formed of variable speeds from 1mm/s to 1000mm/s in ascending order and using a ball on disc method. A precision steel ball was used together with a 46mm diameter silicon disc. Before the sample reached the required temperature of 37°c, the machine was set at an idle speed and the ball applied no load to the sample or the disc. Once the temperature was equilibrated the ball applied a load of 2N and the test run began. Test were carried out on all samples in triplicate, -20°c normal samples and -80°c cycled samples. A new silicone disc was used for each new triplicate. Before the tests were carried out, the discs were cleaned using detergent to remove any grease residue that may have been left from manufacture. The steel ball was cleaned using an ultrasonic cleaner between each triplicate. The sample pot of the tribometer was also rinsed with hot water and ethanol after each run.

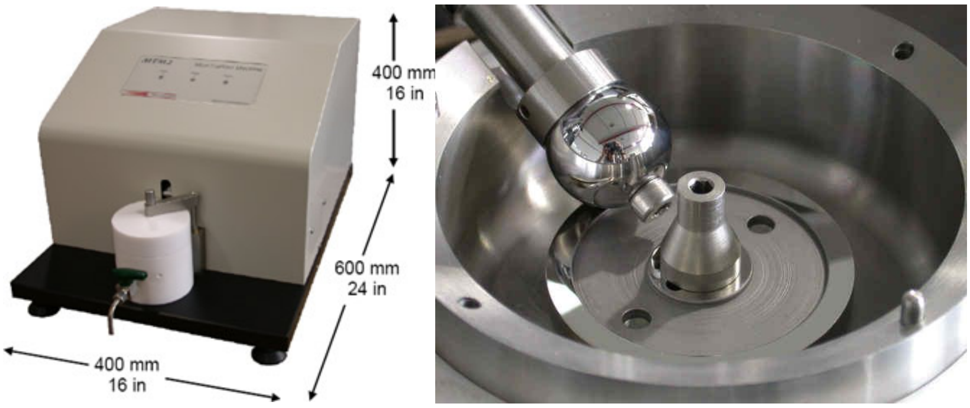


Figure 5.1: Photograph of tribometer

5.1.5 Differential Scanning Calorimetry

Differential scanning calorimetry was used to monitor physical state transformations for the ice creams. A Perkin Elmer DSC 7 using Pyris software was used. Thermal transitions were evaluated by DSC experiments in temperature ranges from -80°c to +40°c through quantification of energy released (or absorbed) during heating (or cooling) at 10°c a minute. Samples were weighed and sealed in aluminium pans, with an empty pan as a reference. The sample pan could hold a total of 40ul of liquid sample, and the ice cream sample was melted before being added to the sample pan. The emulsion sample was weighed and crimped inside the aluminium pans. The sample pan was then placed inside the DSC machine along side the empty sealed reference pan. Heat flow was recorded as a function of time. Two cycles were chosen. The first was

- Hold for 5 minutes at -20˚c
- Heat from -20˚c to 40˚c at 10˚c/min
- Hold for 5min at 40˚c
- Cool from 40˚C to -20˚C at 10˚c/min

These were done for all samples, both -20°c normal and -80°c cycled. However, early results indicted that -20°c was not a low enough temperature to gauge cooling rate, therefore all samples were then run again cooling down to -80°c. That cycle was

- Hold for 5 minutes at -80˚c
- Heat from -80˚c to 40˚c at 10˚c/min
- Hold for 5min at 40˚c
- Cool from 40˚C to -80˚C at 10˚c/min

Both of these cycles were then repeated in triplicate with the same sample. The purpose for such a rapid temperature change was to try and mimic in mouth temperature change when eating ice cream.

5.1.6 Particle size analysis

All the ice cream samples were analyzed for their fat droplet size and distribution and determination of their mean volume diameter. This size parameter was deuced from integrated laser light scattering measurements by using a Mastersizer (Malvern mastersizer). Samples were brought to room temperature and gently stirred before sampling and dilution in distilled water was approx 1:1000. The presentation factor was selected by measuring the refractive index of dispersed fat relative to water. The mastersizer was then cleaned out with deacon and distilled water between each sample run

5.2 Results and discussion

5.2.1 Rhelology measurements

Rheology aims to measure the elastic and viscous properties of a material. In order to measure the visco elastic properties in the four ice cream samples a varying amount of stress or strain is input into the sample, whilst the corresponding stress or strain is measured.

The fat content of the samples has an impact on the elastic and viscous moduli increasing a more liquid like behaviour to be present in the samples. This is due to the fat acting as a lubricant. Authors such as Subramanian *et al* (2006) and Adapa *et al* (2000) concluded that fat reduction in dairy products resulted in increased viscoelastic properties and that the amount of fat and degree of fat destabilization affected the elasticity. Adapa *et al* also found that fat replacers (both protein and carbohydrate based) did not enhance the elastic properties but did increase the viscosity of frozen ice cream mixes. Milk fat, like that used in the Mackie's samples (16% whipping cream) interacts with the other ice cream ingredients to develop the overall mouth feel sensation, and the introduction of protein based fat replacements can have an impact on this sensation. Guinard *et al* (1996) found that ice cream with a higher fat content had higher flavour and texture ratings, and this was the case in the previous sensory experiments in chapter 4 with creaminess ratings, however, this did not influence the overall amount of ice cream consumed. 'Creaminess', a hard word to define, as discussed in the literature review, is often related to fat and mouth coating, and therefore a rheological assessment of the samples used will give an insight into physical measurements such as the viscolelasticty of the samples, and whether these correlate with the sensory information gathered previously.

The results are shown for the viscosity as a function of shear rate in Figure 5.2. These were carried out for each of the four samples ('normal' Sainsbury's and Mackie's, and 'cycled' Sainsbury's and Mackie's) at 37°c (mouth temperature).

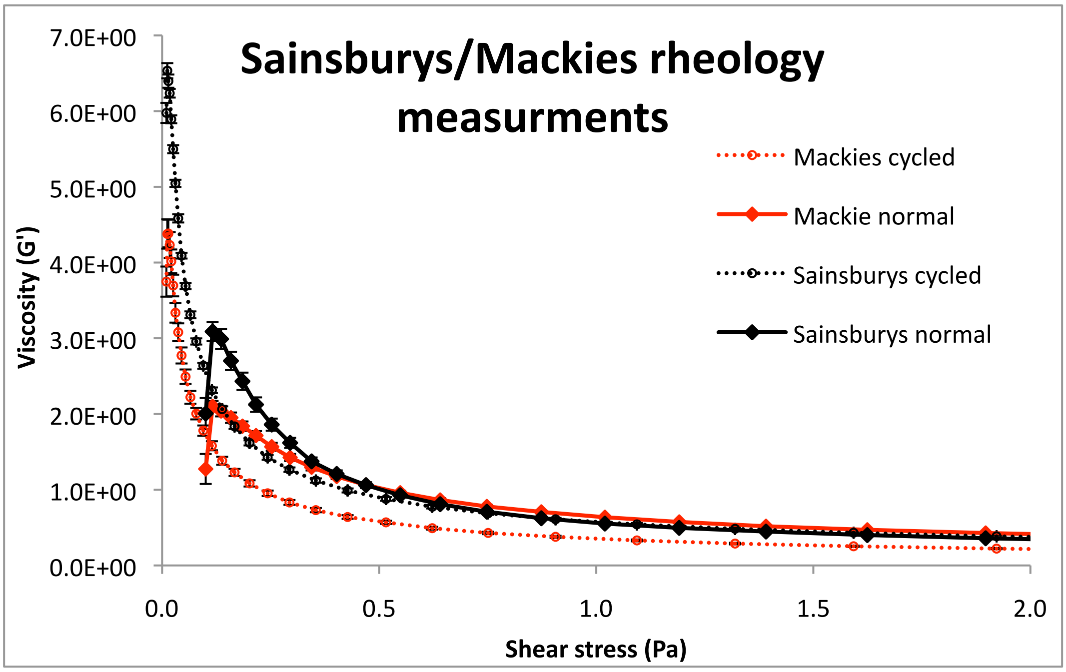


Figure 5.2: Rheological measurements

As identified the from the results gathered, there is an initial difference in the viscosity of both the normal Mackie's and normal Sainsbury's samples, with the normal Sainsbury's sample having an initially higher viscosity than the Mackie's. This is inline with previous findings of and Adapa *et al* (2000) who concluded that fat reduction in dairy products resulted in increased viscoelastic properties. This was also apparent in the temperature-cycled samples. The biggest different however, seems to lie between the cycled vs. normal samples, with the temperature cycled samples showing higher initial viscosity than the normal sample counterparts. As viscosity can be related to in mouth creaminess, it is interesting to note that with the normal samples in previous chapters, that it was the Mackie's that scored higher than the Sainsbury's for creaminess rating. Stokes (2013) describes rheology as a technique "used to develop constitutive relationships between stress and strain rate, and foods are generally more complex than most materials because they are also strongly dependent on time scales of the deformation process (thixotropy, elasticity, etc.) as well as shear and thermal history (processing)." The triangle of 'rheology-structure-processing' still requires much research and more in depth study is required to better develop models for intact food and further more to understand how food behaves under the conditions that are present during oral processing.

5.2.2 Tribology measurements

Tribology is the study of friction and lubrication between interacting surfaces in motion. These interacting surfaces in the mouth during food consumption is plentiful: teeth–teeth, tongue–palate, tongue–teeth, teeth–food, tongue–food, etc. Dresselhuis *et al* (2007) demonstrated an inverse relation between fat perception and in mouth friction sensed between the tongue and the palate. Evidence also suggested that oil in water emulsions, which have an increased sensitivity to coalescence, give rise to a lower friction rate, both in measurement and oral perception, which leads in enhanced fat perception.

While setting up the tribometer, triplicate experiments were first carried out with distilled water to test the tribometer response to simple systems. Through this, it was decided that with the ice cream samples, the silicone-backing mat would be changed after each triplicate was undertaken. From Figure 5 to Figure 5.5 show the traction coefficients for the Sainsbury's normal/cycled and Mackie's normal/cycled.

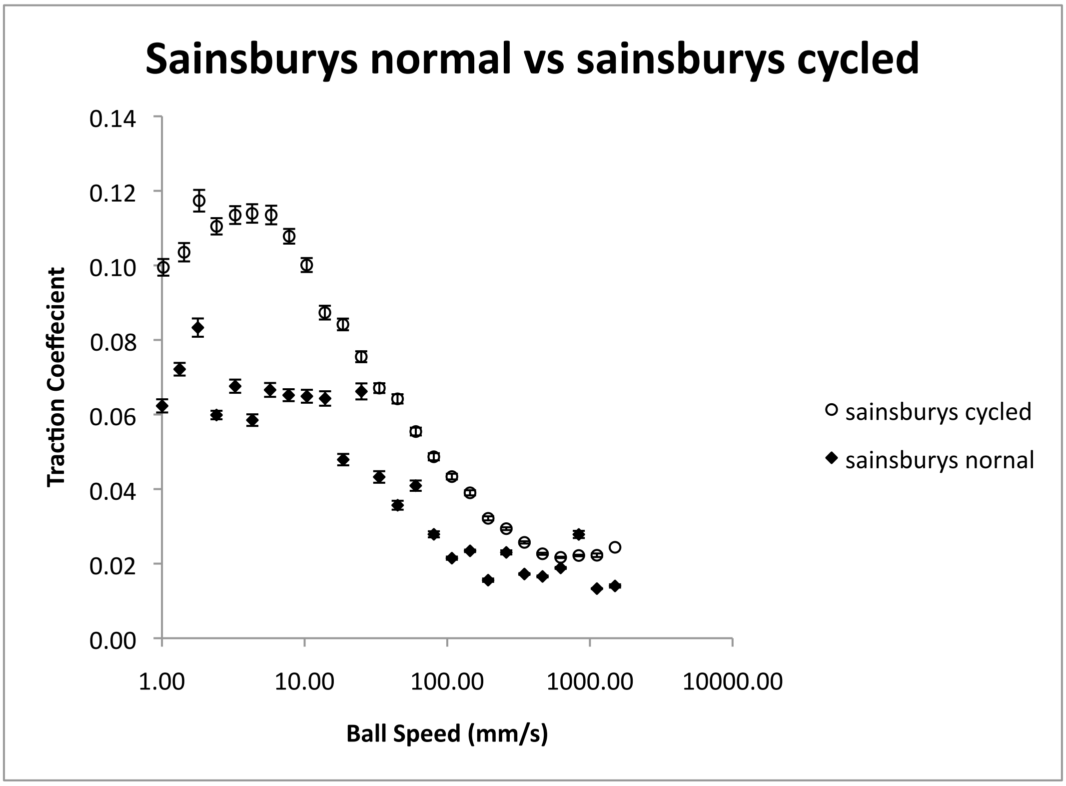


Figure 5.3: Sainsbury's normal and Sainsbury's cycled tribometer data

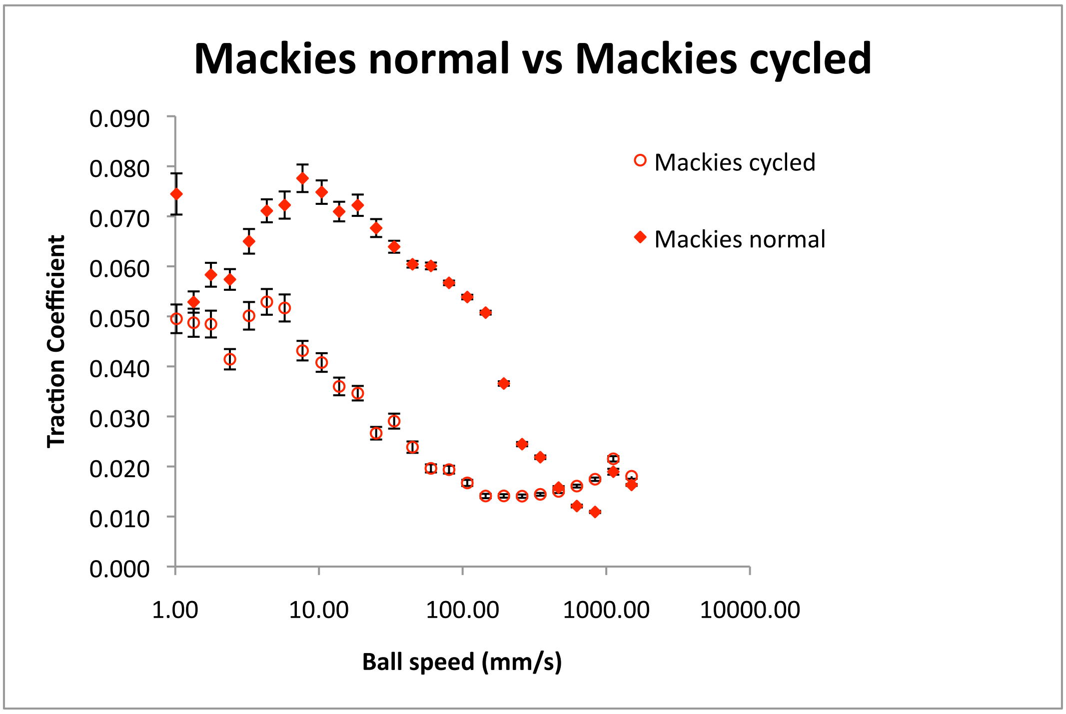


Figure 5.4: Mackie's normal/cycled tribometer results

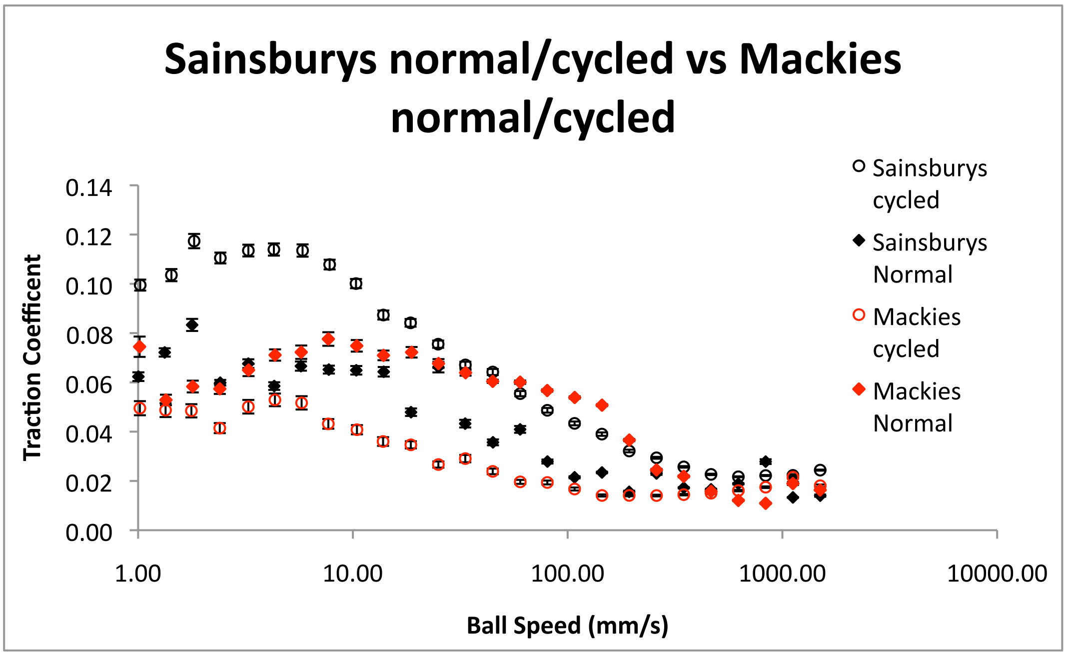


Figure 5.5: Sainsbury's normal/cycled vs. Mackie's normal/cycled tribometer results

Figure 5.5 illustrates the response of the tribometer to the four ice cream samples at 37° c which replicates in mouth temperature. It can be identified that that the traction coefficient begins higher in all samples when ball speed is low, but as speed increases the traction coefficient become decidedly lower. Between the two normal samples, the traction coefficient are very similar but begins higher for the normal Mackie's normal sample than the Sainsbury's normal sample which could be due to the difference in fat types between the samples. However, results indicate that the Sainsbury's cycled sample has the highest traction coefficient, and the Mackie's cycled sample has the lowest.

From this graph it can be seen that the all the ice cream samples at 37 °c have sufficient lubrication beginning at 0.12 traction coefficient and steadily decreasing as ball speed increases, decreasing to below 0.02.

The Mackie's cycled sample has decidedly more lubrication, as the traction coefficient for the sample begins lower than the other samples at 0.05. This could be down to the use of cream in the ice cream. This can also be related to the particle size of the samples with both the Mackie's normal and cycled samples having smaller particle size than either of the Sainsbury's samples, with in mouth lubrication deforming the Mackie's samples more easily than the Sainsbury's.

Comparing these results to the samples used in Chapter 3 (Sainsbury's basics and Green & Blacks) show large differences, as the Green & Blacks and Sainsbury's basics yielded more similar results than the Sainsbury's basics and the Mackie's.

Whilst this graph cannot yield a result from about perceived creaminess, it would be hypothesized from this graph that between the normal ice cream samples, the

Mackie’s would give a fuller and longer lasting mouth feel than the Sainsbury’s as the traction coefficient for the Sainsbury’s basics is lower, and would therefore it could be perceived as more greasy, and this is what was found in Chapter 4 results, however, this did not seem to impact on how much participants ate overall. However, this changes for the cycled samples, indicating that once cycled, the Mackie sample drops in lubricating properties, whilst the Sainsbury’s cycled increases due to ice crystal. This may be due to crystal size is a gross change and air cell disruption. Participants in the triangle test indicated grittiness and rough textures when describing the cycled samples, which indicates that whilst they are insensitive to fat change, they are sensitive to changes in ice, which is not good when trying to limit fat intake. The air cell disruption caused by the cycling could also have lead to the ‘orangey flavour’ that some participants indicated, due to large fat droplets and the vanilla delivery in mouth.

5.2.3 Particle droplet size

The influence of ice cream type and cycle on particle size was considered, and ‘particle size’ discussed in the following section refers to mean particle size. Fig 5.6 shows that particle size distribution is demonstrably different between the ice cream types with the Mackie’s normal and cycled showing distribution <2μm, compared the to Sainsbury’s normal and cycled >20μm for volume weight (D4, 3). This could be down to the different fat type and content between the ice creams. Whilst both the Sainsbury’s normal and cycled have larger particle sizes than the Mackie’s samples, in mouth detection levels are still low (<50μm). However, when considering the results gathered in Chapter 4, it is important to remember that in the taste test results from the cycled samples, indicated that participants acknowledged a ‘grittier’ mouth feel with the cycled Sainsbury’s samples when compared to the Mackie’s cycled. However, both cycled samples mean fat particle size for both Mackie’s and Sainsbury’s are smaller than their normal counterparts

Data has indicated that vegetable fats, such as those used in the Sainsbury’s samples needed greater fat globule destabilisation, as their chains were unsaturated and longer. The fat globule organisation supports other micro structural elements in the ice cream and it is shown here that it influences particle size which illustrates the partial coalescence of the fat globules, which lends itself to overall mouth feel from the product.

Table 5.2: Particle size (Volume/weight) for normal and cycled samples

Ice cream type	D[4,3] μm	D[3.2] μm	d (0.1)	d(0.5)	d(0.9)
Sainsbury’s Normal	23.34	0.75	0.22	8.08	65.2
Mackie’s Normal	1.79	0.26	0.11	0.41	2.19
Sainsbury’s cycled	20.9	0.85	0.25	10.6	47.7
Mackie’s cycled	1.50	0.25	1.11	0.40	1.72

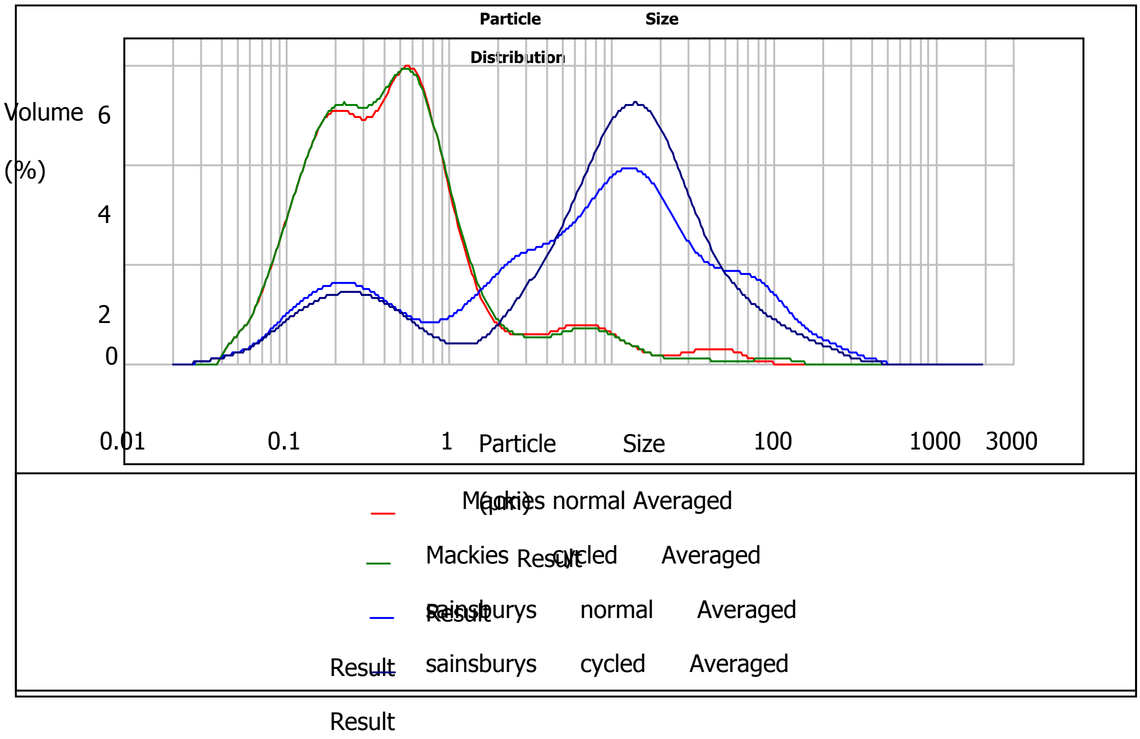


Figure 5.6: Particle size for normal and cycled samples

5.2.4 Differential scanning calormetry

The samples were heated to 40°c and then cooled from 40°c to -80°c. Heat flow was recorded as a function of increasing or decreasing temperature. For each sample, the experiment was conducted in triplicate. The percentage of crystalline matter had hoped to be calculated, however, due to the exact nature of the fats being unknown- as companies were not willing to divulge such information- this could not be done.

Heating and cooling curves were obtained from the normal and cycled ice cream samples. The initial stage was to warm the ice cream and take it to around body temperature (between 37°c-40°c) before then cooling it again back down to -80°c. Both fat droplet size and emulsion stability can influence fat crystallisation. Table 5.3 shows the peak analysis of the thermal behaviour for the normal and cycled ice cream samples. The DSC was used to characterise the thermal behaviour of the ice cream samples on heating and cooing DSC exhibited peak ranging from -20°c to 10°c, some of which can be attributed to free water. Figure 5.7 shows that both the normal samples when heated required greater heat flow to cause the samples to melt, when compared to the cycled samples. Below -20°c the heat capacity of the entire sample is nearly constant. Between -20°c and -2°c the ice content of the samples decreases rapidly, which appears as the peaks in the graph. The heat capacity of melted ice cream is larger than that of frozen ice cream because the heat capacity of water is larger than that of ice (Clarke, 2008). The cycled samples melting point was slightly higher than the normal samples. This could be due to the increased ice crystal size taking longer to melt, as it would be expected that some form of Ostwald ripening would have taken place during the cycling of the ice creams between -80°c and -20°c, even if it was just a small amount. This would in turn affect the fat phase of the ice creams. It is well accepted that the type of fat used in ice cream formulation influences ice cream characteristics, and these characterises would have been further changed through the temperature abuse that took place.

With regards cooling of the samples, re-freezing of the samples peaked initially for the cycled Sainsbury's sample before any of the other samples.

Table 5.3: Heating peak analysis of thermal properties of ice cream

Ice cream	Heating peak			
	Onset temperature (°c)	Peak	End of peak (°c)	Area (Jg-1)
Sainsbury's normal	-29.48	-2.00	5.22	187.82
Mackie's normal	-28.26	2.01	7.01	180.93
Sainsbury's cycled	-23.80	1.78	11.43	217.72
Mackie's cycled	-27.38	0.45	10.29	196.05

Table 5.4: Cooling peak analysis of thermal properties of ice cream

Ice cream	Cooling peak			
	Onset temperature (°c)	Peak	End of peak (°c)	Area (Jg-1)
Sainsbury's normal	-19.77	-17.84	-33.09	-197.41
Mackie's normal	-19.87	-17.76	-29.58	-201.87
Sainsbury's cycled	-16.64	-15.68	-28.89	-221.32
Mackie's cycled	-20.13	19.06	-29.58	-206.81

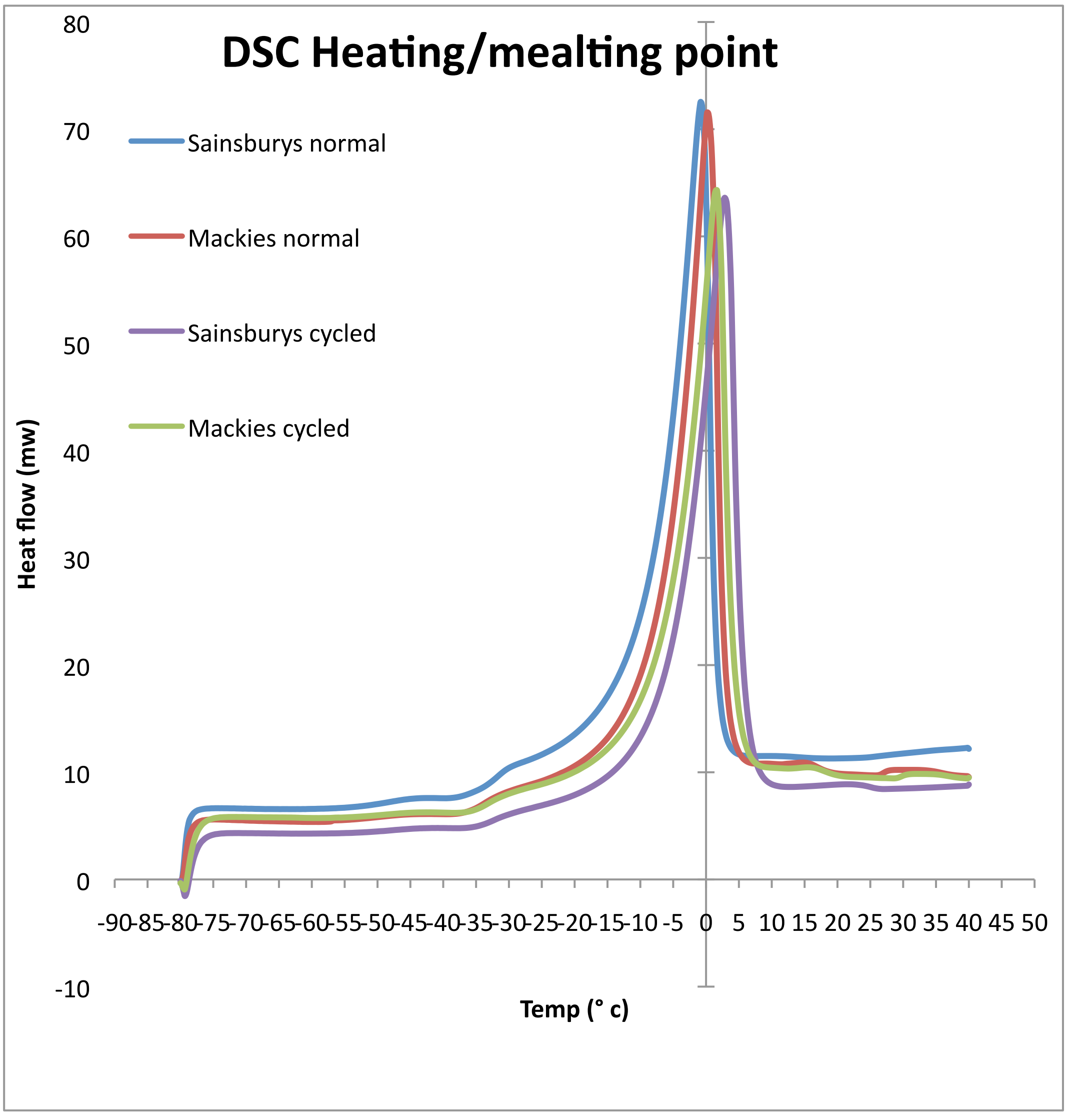


Figure 5.7: Heating/melting point of ice creams

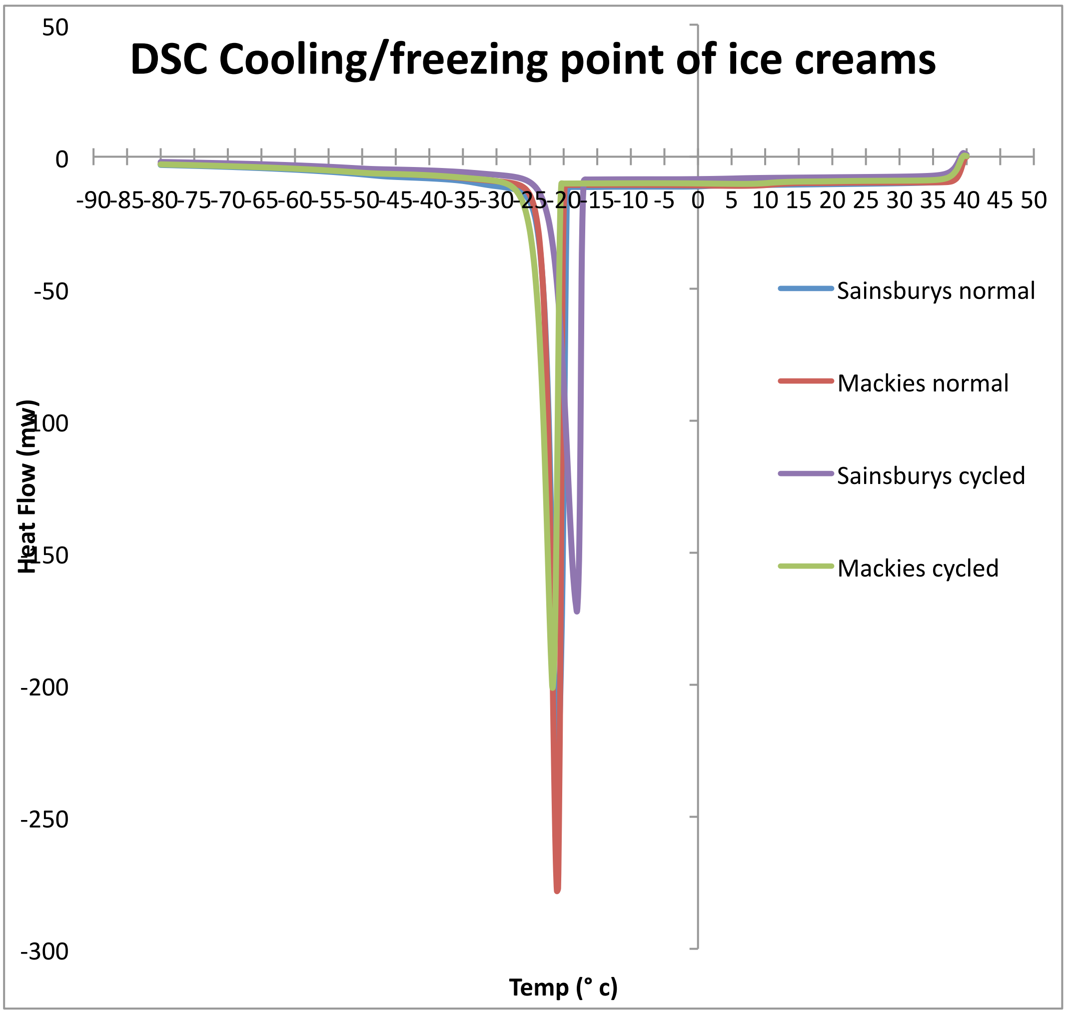
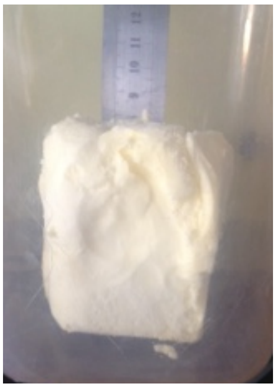
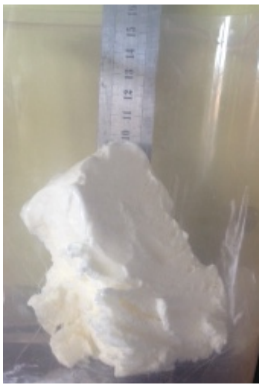
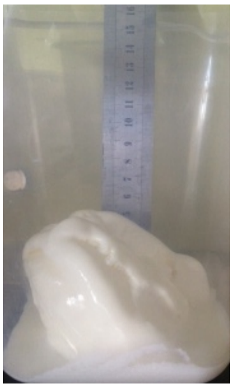
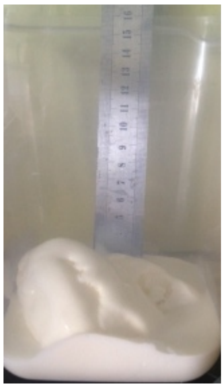
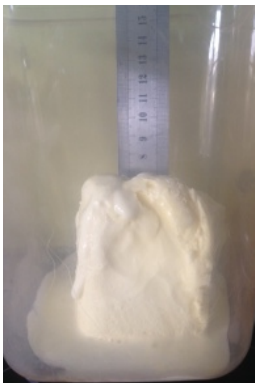
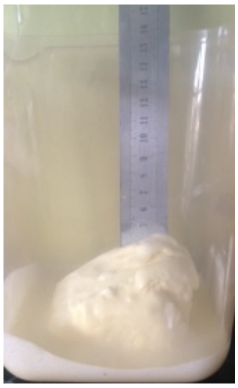
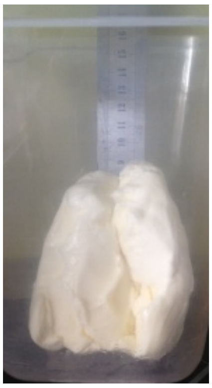
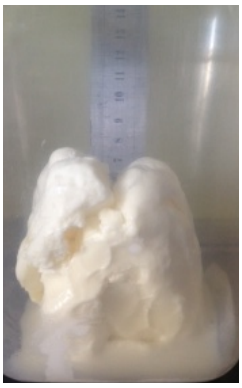


Figure 5.8: Cooling/freezing point of ice creams

5.2.5 Meltdown and Slumping

The slumping and meltdown of all four samples was investigated. This was done to witness the stability of the ice creams at different temperatures and also to understand if ice cream melting behaviour is formulation dependant, and whether temperature abuse of this formulation impacts on melting behaviour. The results are tabulated with photographs and graph form.

Table 5.5: Representative photographs of ice cream samples at 25°c

	0 mins	15mins	30mins
Sainsbury's normal			
Mackie's normal			
Sainsbury's cycled			
Mackie's cycled			

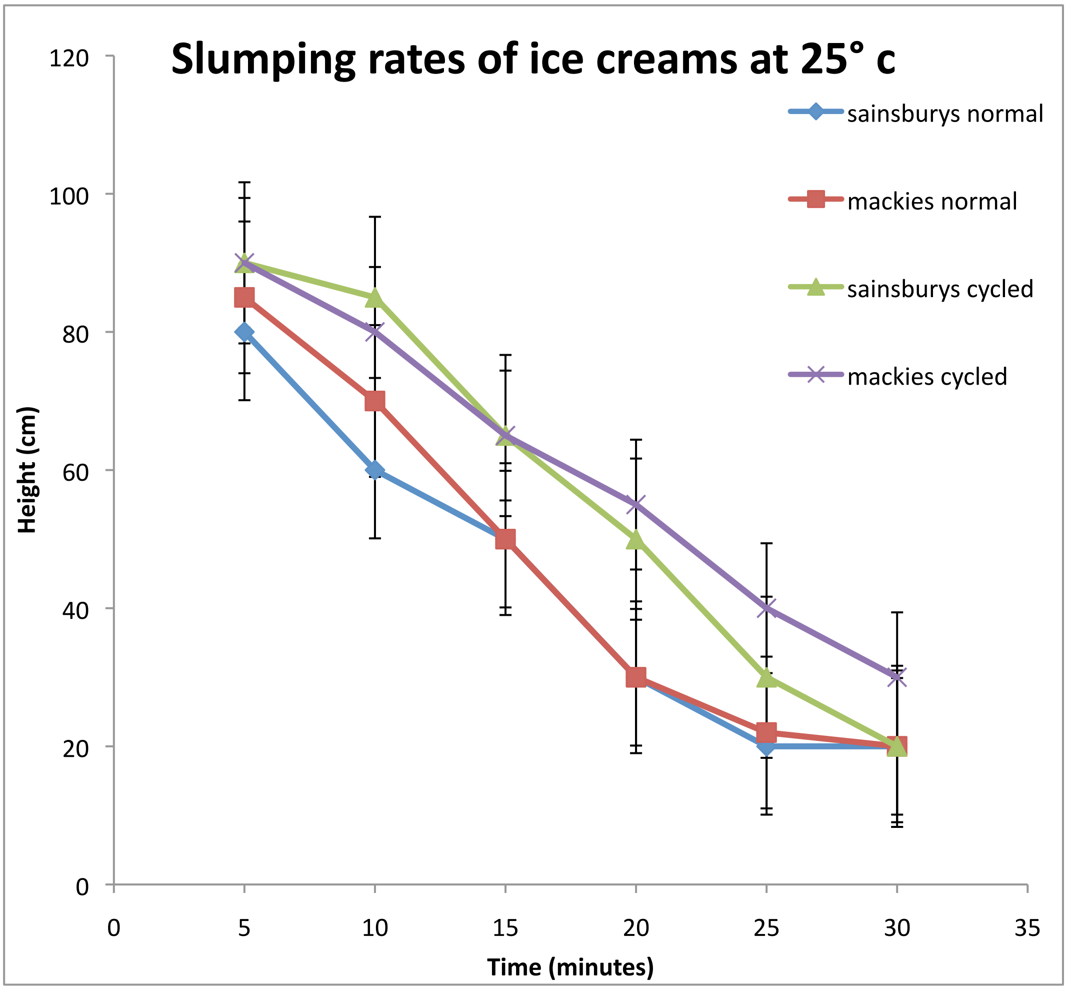
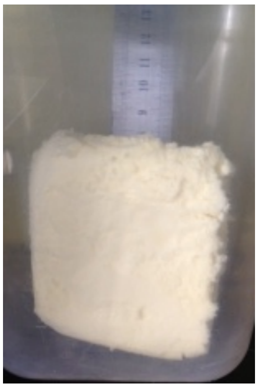
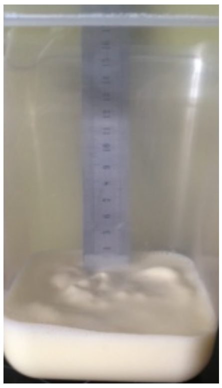
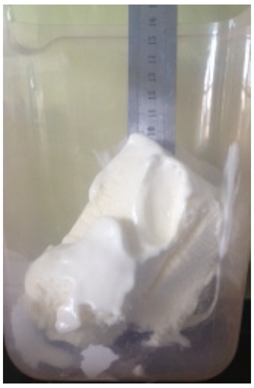
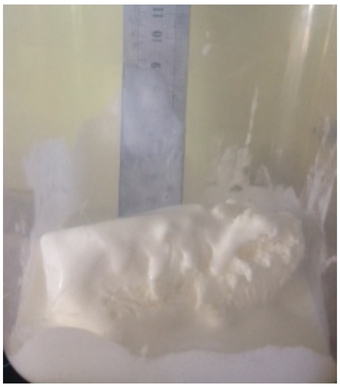
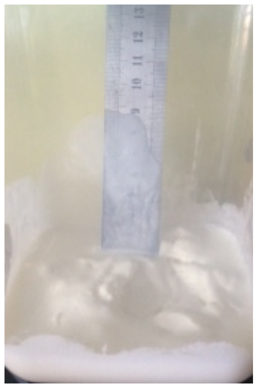


Figure 5.9: Slumping of ice creams at 25°c over time

Table 5.6: Representative photographs of ice cream samples at 37°c

	0 mins	15mins	30mins
Sainsbury's normal			
Mackie's normal			
Sainsbury's cycled			
Mackie's cycled			

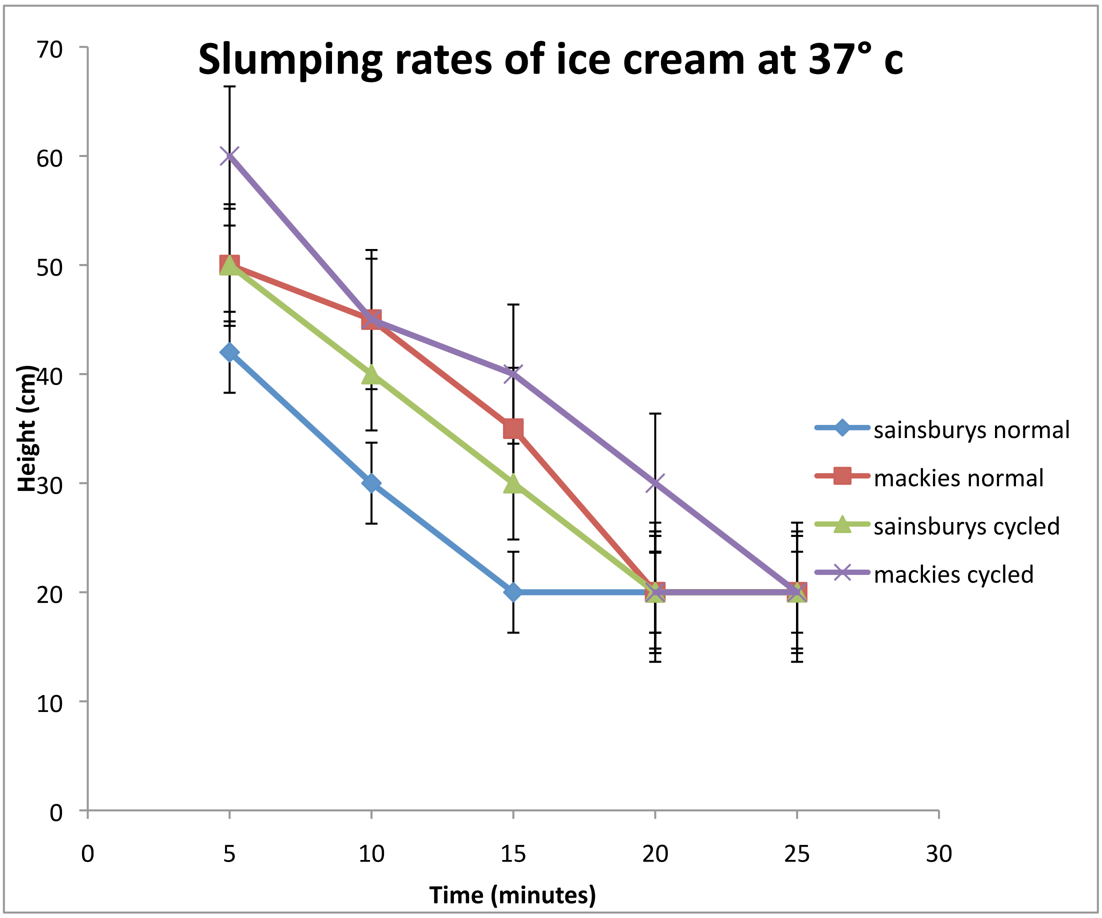


Figure 5.10: Slumping of ice creams at 37°c over time

In the slumping and meltdown experiments at room temperature (25°c) all four samples had not melted completely by the 30 minutes, and there was still semi solid ice cream present. However, it is clear from the photographs taken than slumping did take place. At 37°c by 15 minutes, all samples had slumped and by 30 minutes, all samples had melted into a liquid. In both temperature experiments, the cycled samples took longer to melt than their normal counterparts, indicating that there may be potential larger ice crystal sizes present, which are taking longer to melt. The amount and type of stabilizer used in each formulation may also contribute to the melting capabilities. Even though the stabilizers were in fact the same in both formulations (Guar gum and sodium alginate) this would indicate the that it would be the amounts used. Whilst the emulsion of ice cream is relatively robust, as seen in the creaming profiles in Chapter 2, it is the presence of the ice crystals melting that is causing the slumping. However, even though these samples slumped by 30 minutes, this did not seen to impact upon the eating rate data previously shown as all the participants had eaten the samples within 15 minutes. The error bars show the standard deviation between the samples.

During ice cream manufacture, Drewett and Hartel (2007) found that residence time in the freezer had the largest impact on ice crystal size. When the ice cream was frozen quicker, smaller ice crystals were formed, and also, that lower draw temperatures reduced recrystalization rates, which aided in keeping the ice crystals at a smaller size. They also found that sweeteners did not adversely affect ice crystal formation in the ice cream.

Wildmoser *et al* (2004) investigated the impact of using low temperature extrusion freezer process on the influence of ice crystal size when compared to conventional freezing methods. Low temperature extrusion was found to have a beneficial impact on the ice crystal size by keeping the ice crystal size small. This was then shown to have improved the sensorial properties of the ice cream, such as scoop ability, melting behaviour and creaminess.

These result indicate that the Mackie's ice cream took longer to slump and meltdown in both the normal and cycled samples at 37°c, which would show that they take longer to melt in mouth, leading to a creamier mouth feel, which was shown in the first experiment in Chapter 4 with human participants.

5.3 Thesis conclusions and future work

Ice cream remains one of the most complex foodstuffs currently available. Not just from a structural, formulation and manufacturing level, but also in the context of consumer perception and eating behaviour. Results show that even though ice cream can vary drastically in ingredients and formulation, this does not necessarily translate to drastic structural changes, meaning that robust manufacturing process must be in place for commercial ice creams. Also, that there is a general lack of overall sensitivity to absolute structure, but a preference to flavour and presentation. By testing the limits of human sensitivity, in terms of eating behaviour, i.e. humans are very insensitive to levels of incorporated fat, which gives scope for a huge potential for calorific intake. This can however, be affected through gross structural change of the ice crystal phase, certainly in terms of preference. Further work needs to be conducted into the possibility of this affecting eating rate and total intake. Future work could also include development of own formulations, perhaps in conjunction with industry. Following on form the results gathered from the triangle test, an exploration of the 'orangey' flavour that was described by some participants could be investigated. The impact of visual cues, such as vanilla seeds and colour differences in vanilla ice cream brands on eating behaviour could also be investigated.

Another interesting conclusion was the limitation of tribology. Over recent years, tribology has become a method of which, it has been believed, could mimic human in mouth conditions. However, results gathered show that the machine is much more sensitive to lubrication than human participants. Also that participant's perception was to a 'gritty/icy' mouth feel, rather than to lubricity.

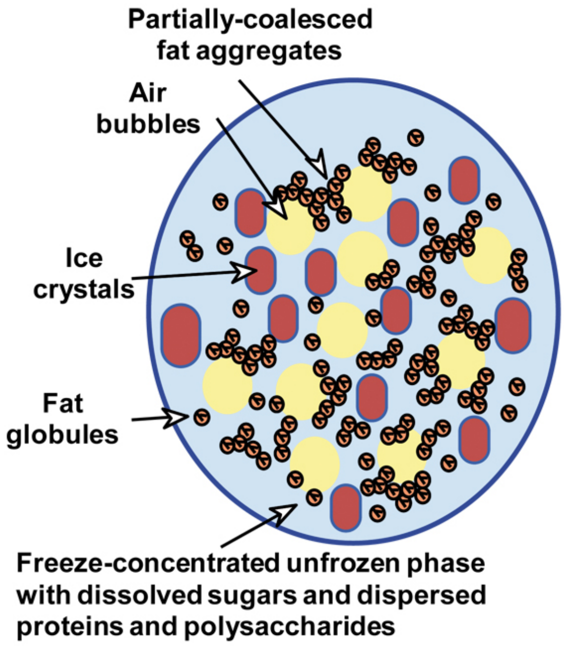
Limitations include the lack of ice crystal measurement data. Whilst some Cryo SEM was conducted, this data was lost. Ice crystal size is by its very nature difficult to measure. Typically ice cream cycling will yield an ice crystal size of upwards of 100μm, compared to a fresh ice cream sample where the ice crystal size is around 40μm. However there was a clear difference in ice crystal size between the 'normal' and 'cycled' samples and gross increase in ice crystal size was present due to cycling. Phase transition is rapid due to heating in mouth and difficult measure. There is a continued need for decent methods of detangling when dealing with such a complex formulation and is also restrictive as cold temperatures are needed. There was also the issue of no cryo laboratory being available.

It is also important to address the issue to collaboration between two different areas of research. It was not something had been tried before. There was a great synergy in levels of care taken throughout, however, regards presentation of data there was a total disconnect. Although there are psychology elements imbedded, an engineering perspective to the thesis was taken.

Appendix

Chapter 1

Diagram of microstructure of ice cream



Chapter 2

Ice cream Questionnaire

This is a brief questionnaire on ice cream. The purpose of this questionnaire is to gauge a better understanding of consumers eating and purchasing habits of ice cream. Participation in this questionnaire is completely voluntary and you can withdraw from participation at any time, even after completion. Your answers and personal details will be kept strictly confidential, and will be kept for the purposes of contacting you for possible further experiments regarding this study. It should take around 5 minutes to complete.

Please complete each field as best as you can, and tick or circle answers when asked.

If you have any questions regarding this questionnaire, please feel free to contact me at .

Thank you for your participation in this study.

Sarah Santos-Murphy

PhD Student

Name:

Age (in years and months):

Sex (please circle): Male/Female

University email address:

Question 1. Do you eat ice cream? Please circle answer

a) Yes
b) No

Question 2. How often do you eat ice cream? Please circle answer

a) Once a week
b) Once a month
c) Once every 6 months
d) Once a year
e) Never

Question 3. Where do you purchase ice cream? Please tick boxes

	Never	Sometimes	Often	Always
a) Supermarket	[ ]	[ ]	[ ]	[ ]
b) Ice cream van	[ ]	[ ]	[ ]	[ ]
c) Cinema	[ ]	[ ]	[ ]	[ ]
d) Corner shop	[ ]	[ ]	[ ]	[ ]
e) Fast food restaurant	[ ]	[ ]	[ ]	[ ]
f) Speciality shop/deli	[ ]	[ ]	[ ]	[ ]

Question 4. Which brands do you purchase? Please tick boxes

	Never	Sometimes	Often	Always
a) Ben & Jerry's	[ ]	[ ]	[ ]	[ ]
b) Cart D'or	[ ]	[ ]	[ ]	[ ]
c) Haagen-Dazs	[ ]	[ ]	[ ]	[ ]
d) Green & Blacks	[ ]	[ ]	[ ]	[ ]
e) Supermarket own brand	[ ]	[ ]	[ ]	[ ]
f) Baskin-Robbins	[ ]	[ ]	[ ]	[ ]
g) McDonalds	[ ]	[ ]	[ ]	[ ]
h) Other- Please state	[ ]	[ ]	[ ]	[ ]

…………………………………………………………………………………………

…………………………………………..

Question 5. Do you prefer soft or hard vanilla ice cream (i.e. soft is Mr. Whippy)?

Please circle answer

a) Soft
b) Hard
c) No preference

Question 6. What types of vanilla ice cream do you purchase? Please tick boxes

	Never	Sometimes	Often	Always
a) Ice cream stick	[ ]	[ ]	[ ]	[ ]
b) Cone	[ ]	[ ]	[ ]	[ ]
c) Cup	[ ]	[ ]	[ ]	[ ]
d) Tub/container	[ ]	[ ]	[ ]	[ ]

Question 7. How do you eat vanilla ice cream? Please tick boxes

	Never	Sometimes	Often	Always
a) Scooped from a tub into a bowl	[ ]	[ ]	[ ]	[ ]

b)Scooped from a tub into a cone	[ ]	[ ]	[ ]	[ ]
c)Scooped from a tub with a hot pudding	[ ]	[ ]	[ ]	[ ]
d) Scooped from a tub with a cold pudding	[ ]	[ ]	[ ]	[ ]
e) As a stand alone pudding	[ ]	[ ]	[ ]	[ ]
f) As a snack	[ ]	[ ]	[ ]	[ ]
g) After lunch	[ ]	[ ]	[ ]	[ ]

Question 8. How important are these factors when purchasing vanilla ice cream? Please tick boxes

	Very Important	Important	Not important	Not at all important
a) Price	[ ]	[ ]	[ ]	[ ]
b) Brand	[ ]	[ ]	[ ]	[ ]
c) Packaging	[ ]	[ ]	[ ]	[ ]
d) Appearance	[ ]	[ ]	[ ]	[ ]

e) Mouth feel	[ ]	[ ]	[ ]	[ ]
f) Taste	[ ]	[ ]	[ ]	[ ]
g) Calorie content	[ ]	[ ]	[ ]	[ ]
h) Soft scoop	[ ]	[ ]	[ ]	[ ]

Question 9. Do you associate certain brands of ice cream with a quality vanilla ice cream? Please circle answer

a) Yes
b) No

If yes, what are these brands? Please write below

Question 10. In your opinion, what are the qualities of a good vanilla ice cream? (I.e. taste, flavour, mouth feel) Please write below

Question 11. Are you a smoker? Please circle answer

a) Yes
b) No

Question 12. Are you, or have you been on a strict diet in the past 6 months?

a) Yes
b) No

Question 13. Do you have any medical conditions/food allergies/ on any medication?

a) Yes
b) No

If yes, please state……………………………………………………………………………………… ………………

Thank you for completing this questionnaire.

Visual Analogue Scale For Portion Size Exercise

Participant Number

Please answer <u>all</u> questions

How HUNGRY do you feel right now?

NOT AT ALL | ______ | EXTREMELY

How FULL do you feel right now?

NOT AT ALL | ______ | EXTREMELY

How strong is your DESIRE to eat ice cream right now?

NOT AT ALL | ______ | EXTREMELY

How MUCH ice cream do you think you can eat right now?

NOT AT ALL | ______ | EXTREMELY

How BLOATED do you feel right now?

NOT AT ALL EXTREMELY

How TASTY was this ice cream?

NOT AT ALL EXTREMELY

How VISUALLY PLEASING was this ice cream?

NOT AT ALL EXTREMELY

How ACCURATE was the serving of this portion size?

NOT AT ALL EXTREMELY

How would you have CHANGED this portion size?

SERVED LESS SERVED

Would you PURCHASE this ice cream to eat at home?

NOT AT ALL LIKELY EXTREMELY LIKELY

How HAPPY do you feel right now?

NOT AT ALL | | EXTREMELY

How SAD do you feel right now?

NOT AT ALL | | EXTREMELY

How STRESSED do you feel right now?

NOT AT ALL | | EXTREMELY

How RELAXED do you feel right now?

NOT AT ALL | | EXTREMELY

How NERVOUS do you feel right now?

NOT AT ALL | | EXTREMELY

How EXCITED do you feel right now?

NOT AT ALL | | EXTREMELY

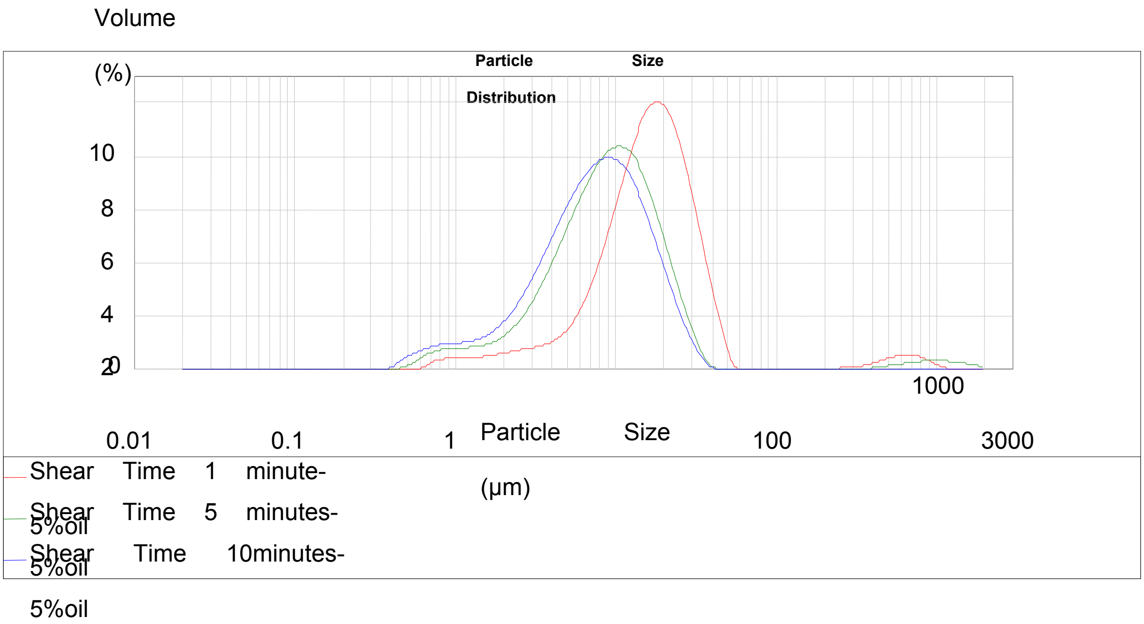
How TIRED do you feel right now?

NOT AT ALL | | EXTREMELY

Thank you

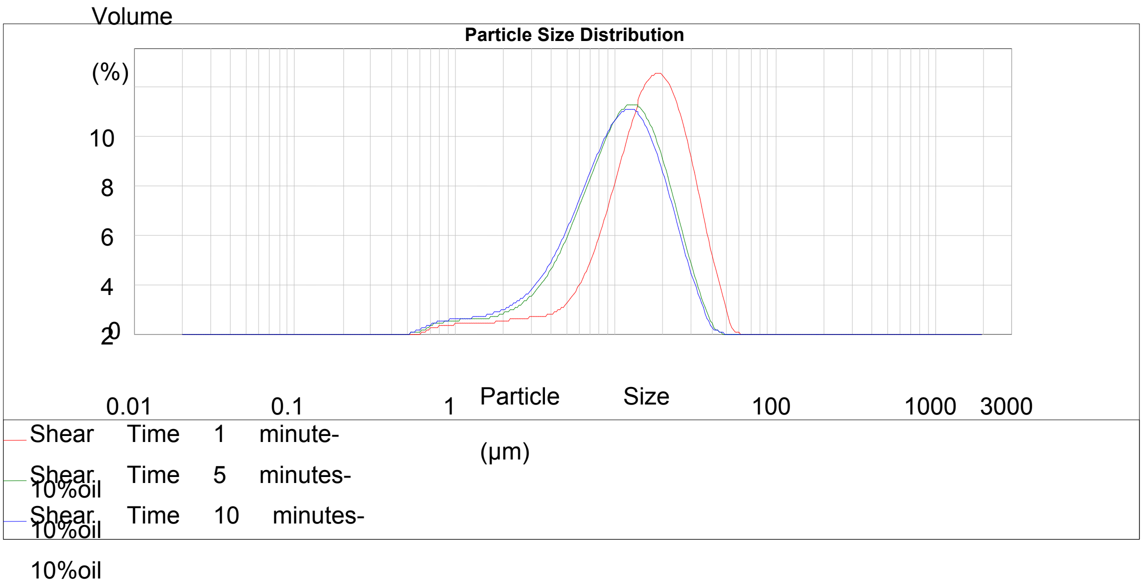
Particle size graphs

Particle Size results for the 5% fat emulsions



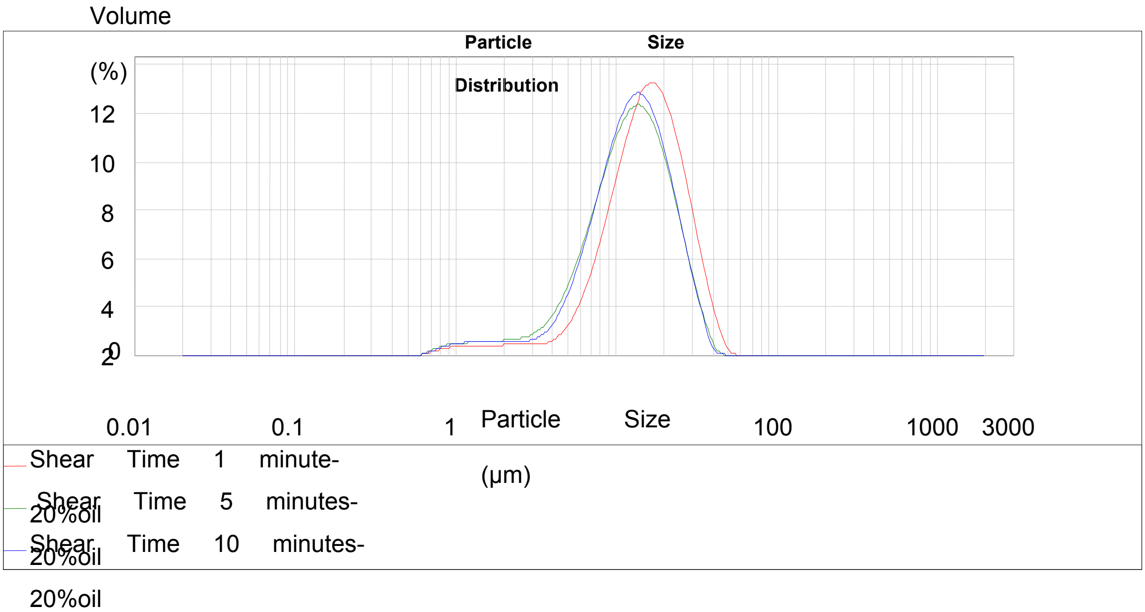
The above figure shows that shearing time does influence fat particle size. Shear time of 1minute gave particle size 16.5μm, shearing time of 5 minutes gave particle size of 9.07 μm and shearing time of 10 minutes gave particle size of 7.6 μm.

Particle Size results for the 10% fat emulsions



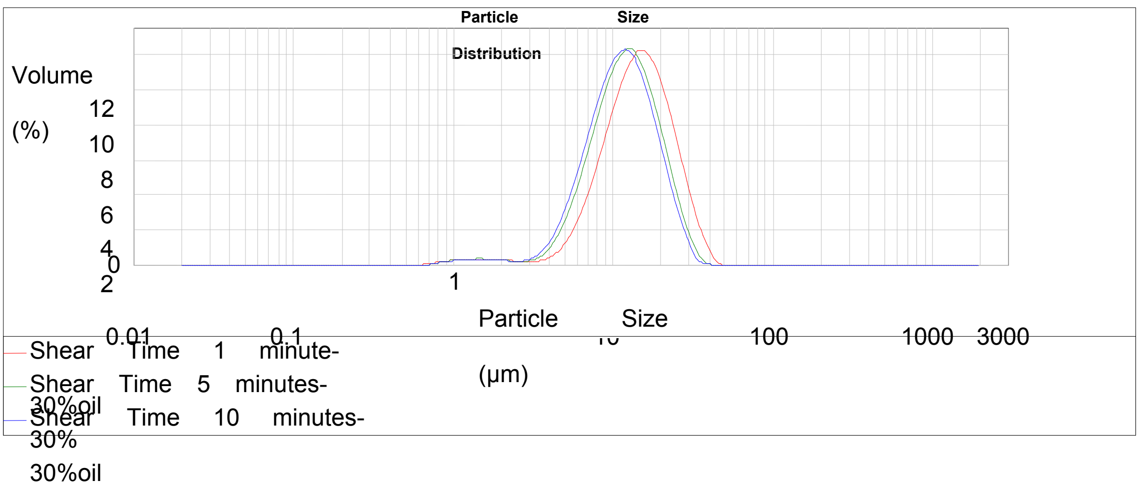
From this graph it can be reported that particle size has increased from the 5% fat emulsion results, as all three results fall above the 10-μm mark. Shear time of 1 minute resulted in very similar fat particle size as the 5%, at 16.8 μm. Shear time of 5 minutes lead to particle size of 11.1μm, and 10.6μm at a shear time of 10 minutes.

Particle Size results for the 20% fat emulsions

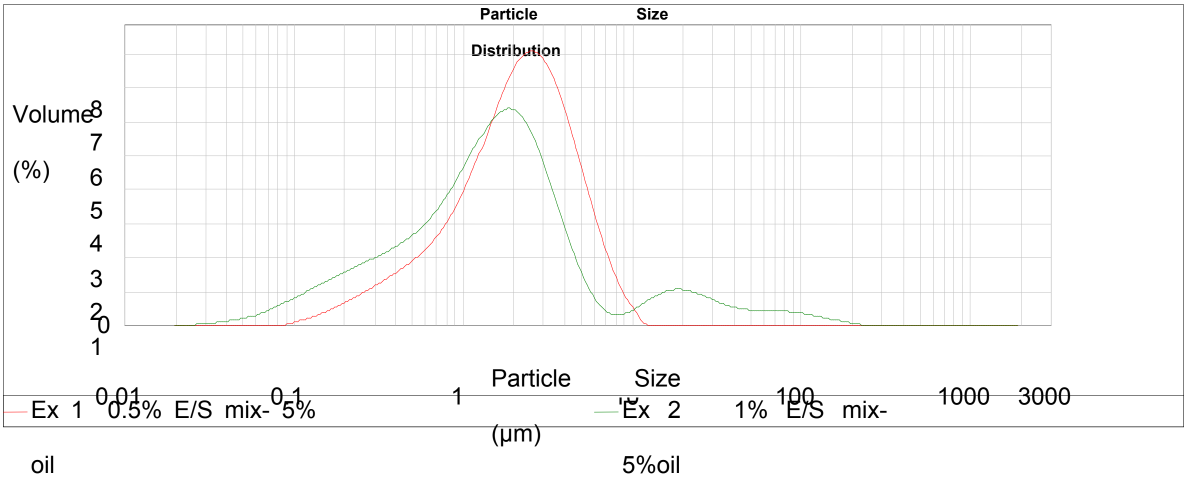


This graph shows that for the shear time of 1 minute, particle size was 15.6μm (decreasing when compared to the 5% and 10% fat emulsions) and 5 and 10 minutes shear time remaining very similar again in particle size at 12.4μm and 12.6μm respectively.

Particle Size results for the 30% fat emulsions

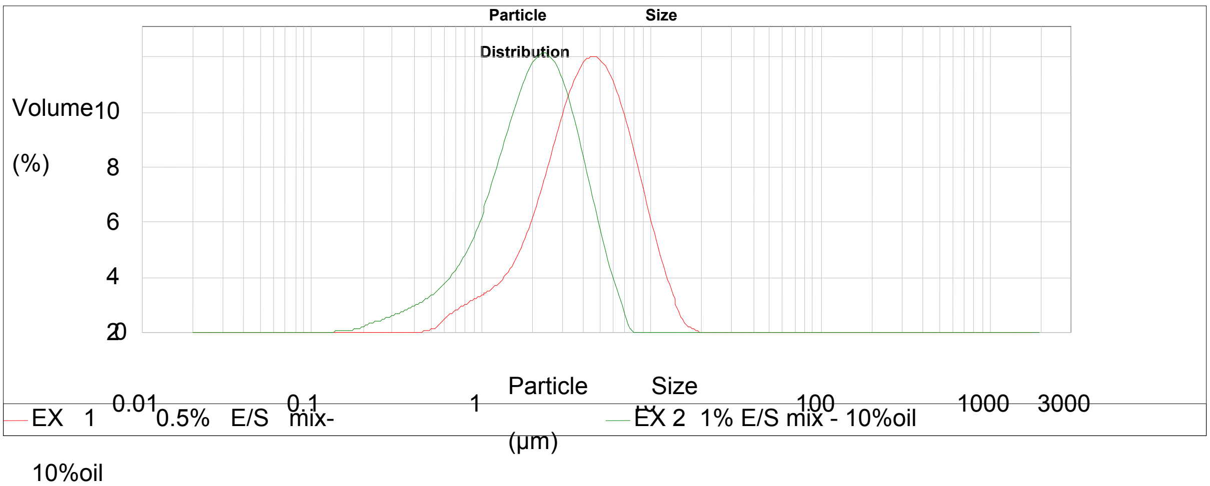


Particle Size for 5% fat emulsions containing emulsifier/stabilizer mix



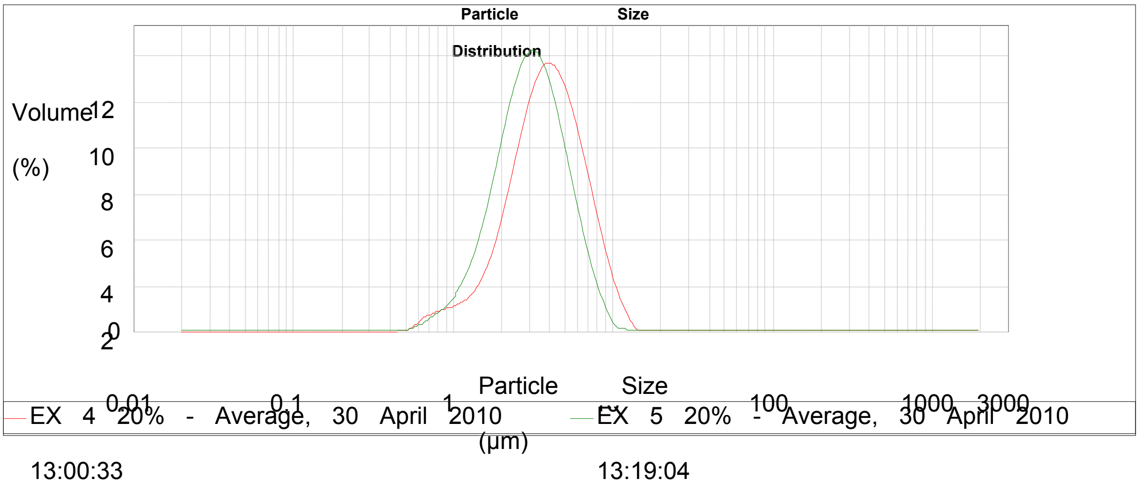
From this graph, it is clear to see that 0.5% emulsifier/stabilizer mix on a 5% fat emulsion results in fat particle size of 2.14 µm, whilst 1% emulsifier/stabilizer mix results in a smaller particle size at 1.53µm.

Particle size for 10% fat emulsions containing emulsifier/stabilizer mix



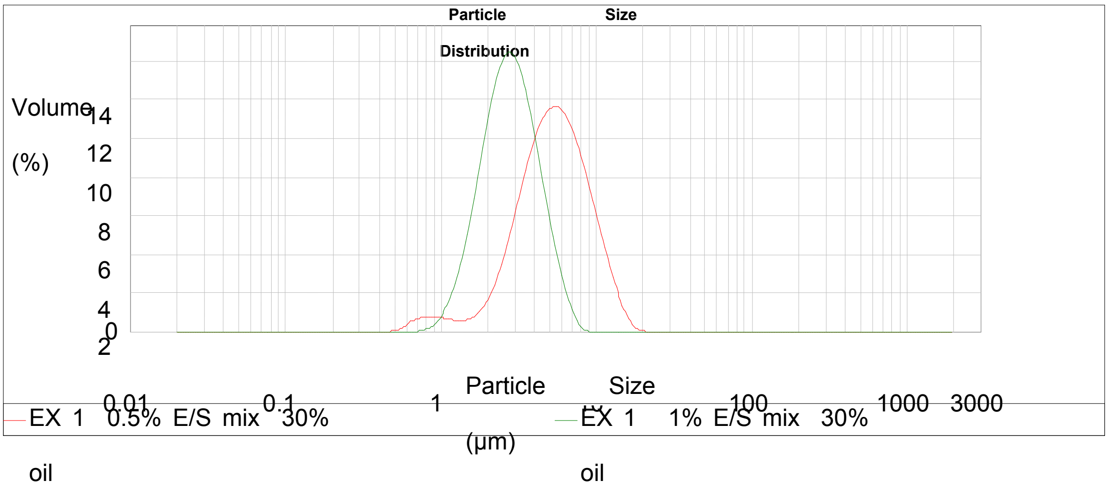
The above figure shows that 0.5% emulsifier stabilizer mix on 10% fat emulsion results in fat particle size of 4.30 μm (greater than that of the 5% fat emulsion at 2.43 μm), whilst the 1% emulsifier/stabilizer mix results in a smaller particle size at 2.11 μm (however, this is still greater than 5% fat emulsion at 1.53 μm)

Particle size for 20% fat emulsions containing emulsifier/stabilizer mix



it is clear to see that the 0.5% emulsifier/stabilizer mixture resulted in a slightly larger particle size of 3.9 μm than that of the 1% mixture at 3.0 μm.

Particle size from 30% fat emulsions containing emulsifier/stabilizer mix

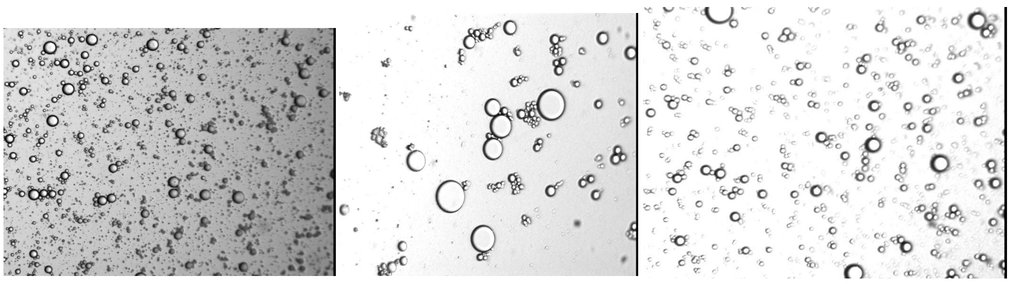


The results show that the influence of the 0.5% emulsifier/stabilizer mixture on a 30% fat emulsion results in fat particle size of 5.32 µm, whilst the 1% emulsifier/stabilizer mixture results in a smaller particle size at 2.80 µm.

Microscopy

5% Fat Micrographs

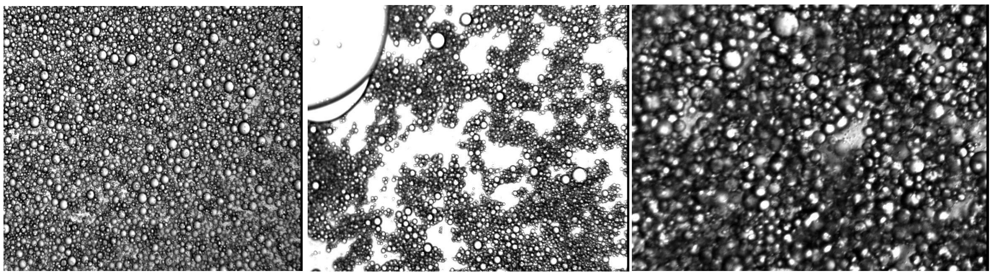
20µm



1 minute 5minutes 10 minutes

30% fat Micrographs

20µm ____________



1 minute 5minutes 10 minute

Some low magnification micrographs were taken at 10x magnification of the samples at their different shear speeds. The micrographs for the 5% fat samples and the 30% fat samples are seen above. As can be seen, the increase of shear speeds leads to smaller and more uniformed fat droplets, and the increase of droplets between 5% and 30% is clear.

Chapter 4

DEBQ scale questionnaire

Please answer all questions. Circle the appropriate response

When you have put on weight do you eat less than you usually do?	not relevant	never	seldom	sometimes	often	very often
Do you try to eat less at mealtimes than you would like to eat?	not relevant	never	seldom	sometimes	often	very often
How often do you refuse food or drink offered to you because you are concerned about your weight?	not relevant	never	seldom	sometimes	often	very often
Do you watch exactly what you eat?	not relevant	never	seldom	sometimes	often	very often
Do you deliberately eat foods that are slimming?	not relevant	never	seldom	sometimes	often	very often
When you have eaten too much, do you eat less than usual the following day?	not relevant	never	seldom	sometimes	often	very often
Do you deliberately eat less in order not to become heavier?	not relevant	never	seldom	sometimes	often	very often
How often do you try not to eat between meals because you are watching your weight?	not relevant	never	seldom	sometimes	often	very often

How often in the evenings do you try not to eat because you are watching your weight?	not relevant	never	seldom	sometimes	often	very often
Do you take your weight into account with what you eat?	not relevant	never	seldom	sometimes	often	very often

If food tastes good to you, do you eat more than usual?	not relevant	never	seldom	sometimes	often	very often
If food smells good, do you eat more than usual?	not relevant	never	seldom	sometimes	often	very often
If you smell something delicious, do you have a desire to eat it?	not relevant	never	seldom	sometimes	often	very often
If you have something delicious to eat, do you eat it straight away?	not relevant	never	seldom	sometimes	often	very often
If you walk past a baker, do you have a desire to buy something delicious?	not relevant	never	seldom	sometimes	often	very often
If you walk past a snackbar or café, do you have a desire to buy something delicious?	not relevant	never	seldom	sometimes	often	very often
If you see others eating, do you also have a desire to eat?	not relevant	never	seldom	sometimes	often	very often
Can you resist eating delicious	not	never	seldom	sometimes	often	very

foods?	relevant				often
Do you eat more than usual, when you see others eating?	not relevant	never	seldom	sometimes	often	very often
When preparing a meal, are you inclined to eat something?	not relevant	never	seldom	sometimes	often	very often

Do you have a desire to eat when you are irritated?	not relevant	never	seldom	sometimes	often	very often
Do you have a desire to eat when you have nothing to do?	not relevant	never	seldom	sometimes	often	very often
Do you have a desire to eat when you are depressed or discouraged?	not relevant	never	seldom	sometimes	often	very often
Do you have a desire to eat when you are feeling lonely?	not relevant	never	seldom	sometimes	often	very often
Do you have a desire to eat when you somebody lets you down?	not relevant	never	seldom	sometimes	often	very often
Do you have a desire to eat when you are cross?	not relevant	never	seldom	sometimes	often	very often
Do you have a desire to eat when you are something unpleasant is about to happen?	not relevant	never	seldom	sometimes	often	very often

Do you get the desire to eat when you are anxious, worried or tense?	not relevant	never	seldom	sometimes	often	very often
Do you have a desire to eat when things are going against you and when things have gone wrong?	not relevant	never	seldom	sometimes	often	very often
Do you have a desire to eat when you are frightened?	Not relevant	never	seldom	sometimes	often	very often
Do you have a desire to eat when you are disappointed?	Not relevant	never	seldom	sometimes	often	very often
Do you have a desire to eat when you are emotionally upset?	Not relevant	never	seldom	sometimes	often	very often
Do you have a desire to eat when you are bored or restless?	not relevant	never	seldom	sometimes	often	very often

Below, please outline what you think this study was investigating

____

____

____

____

Thank you

Volunteer information sheet

UNIVERSITY OF BIRMINGHAM

VOLUNTEER INFORMATION SHEET

An investigation into the palatability of vanilla ice cream

What is the study about?

The aim of the study is to investigate the palatability of vanilla ice cream.

Who is taking part?

Participants are undergraduate and postgraduate students at Birmingham University; there are no inclusion or exclusion criteria, apart from health grounds.

What will I have to do?

You will be required to attend 2 sessions lasting no more than 30 minutes, roughly 2-3 days between the first and second session. You will be required to attend the second session around the same time of day the first session. You will be asked to fill out questionnaires about previous food experiences and required to eat 2 different types of vanilla ice cream.

What are the risks?

These are no perceived potential risks in an experiment of this nature.

What are the benefits?

The study will aid our understanding of the palatability of ice cream and whether this palatability impacts on food preference and they way in which consumers choose and eat ice cream. There will be no direct benefits to you from participating but the information will contribute to wider knowledge about food choice regarding ice cream preference and ways in which these choices could be changed (i.e. promoting healthier food choices).

What if I do not wish to continue at any stage?

You are free to withdraw from the study at any time. You can refuse to answer any question, and may refuse to do anything requested of you.

What happens to the information?

All information is completely confidential to the researcher. All information will be identified by code number, and will be seen only by the researcher. It will not be possible to identify you in any published reports that result from the study.

What else can I expect from the researcher?

You can ask any questions about the study that occur to you during your participation and request a copy of any of the results.

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Consent Form

UNIVERSITY OF BIRMINGHAM

Investigation into the palatability of vanilla ice cream

Consent Form

I have read the Information Sheet for this study and have had the details of the study explained to me. My questions about the study have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I also understand that I am free to withdraw from the study at any time that I can decline to answer any particular questions in the study, and can decline to complete any task requested of me. I agree to provide information to the researchers on the understanding that it is completely confidential. I understand that the information will be stored in manual and electronic files and is subject to the provisions of the Data Protection Act. I acknowledge that the information provided is being used by the University in accordance with the Act.

I confirm that I wish to participate in this study under the conditions set out here and in the Information Sheet.

Signed: ______________________________

Name: ______________________________

Date: ____________________

Researcher: ______________________________

Thank you

Consent Form

UNIVERSITY OF BIRMINGHAM

Consent Form

Triangle test of vanilla ice cream

I have read the Information Sheet for this study and have had the details of the study explained to me. My questions about the study have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I also understand that I am free to withdraw from the study at any time that I can decline to answer any particular questions in the study, and can decline to complete any task requested of me. I agree to provide information to the researchers on the understanding that it is completely confidential. I understand that the information will be stored in manual and electronic files and is subject to the provisions of the Data Protection Act. I acknowledge that the information provided is being used by the University in accordance with the Act.

I confirm that I wish to participate in this study under the conditions set out here and in the Information Sheet.

Signed: ______________________________

Name: ______________________________

Date: ____________________

Researcher: ______________________________

Thank you

Triangle test hand out

Triangle Sensory Test on ice cream

Please take a drink of water before tasting ice cream samples. Eat ice cream samples from left

to right, and please take a sip of water between samples.

Please write down the number of the ice cream which is different than the others.

Please write why you think this ice cream if different to the others:

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