Studies on the Acceptability, Sensory Properties & Consumer Perception of Reformulated Reduced Sodium Ready-Meals

Michelle Mitchell

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Studies on the Acceptability, Sensory Properties & Consumer Perception of Reformulated Reduced Sodium Ready-Meals

By
Michelle Mitchell BSc

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Faculty of Science and Engineering
Department of Life Sciences

Supervisors
Dr. Nigel Brunton, Teagasc Food Research Centre, Ashtown
Dr. Martin Wilkinson, University of Limerick

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Declaration of Originality

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All quotations and summary of the work of others have been acknowledged where appropriate.

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Signed: ____________________________________________

Date: ______________________________________________
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Table of Contents

Title Page .........................................................................................................................i
Declaration of Originality ...............................................................................................ii
Acknowledgements ..........................................................................................................iii
Table of Contents ..............................................................................................................iv
List of Tables ..................................................................................................................x
List of Figures ................................................................................................................xiii
Abstract ............................................................................................................................xvii

1. Literature Review .......................................................................................................1
   1.1 Introduction .............................................................................................................1
   1.2 Salt Production .....................................................................................................2
   1.3 Chemistry of Salt – Sodium Chloride .................................................................3
   1.4 Physiological Role of Sodium Chloride in the body, Recommended Intake
      and Current Consumption Trends .......................................................................5
   1.5 Health Risks Associated with Over Consumption of Salt ...................................9
   1.6 Salt Taste Receptor Interaction .........................................................................14
   1.7 Functions of Salt in Food ....................................................................................16
   1.8 Salt Content of Processed Convenience Foods ...............................................16
   1.9 Ready-Meals in Ireland and Their Reported Salt Content ..................................22
   1.10 Salt and Sodium Labelling of Foods .................................................................25
   1.11 Approaches to Salt Reduction in Food and Their Effect on Sensory
       Properties .............................................................................................................27
       1.11.1 Gradual Salt Reduction - Reduction by Stealth .......................................27
       1.11.2 Salt Substitutes .........................................................................................28
       1.11.3 Flavour Enhancers ....................................................................................31
       1.11.4 Other Salt Reduction Strategies ...............................................................33
   1.12 Sensory Evaluation and Its Importance in the Reformulation Process of
       Food .........................................................................................................................34
   1.13 Thesis Objectives .............................................................................................38

2.1 Abstract
2.2 Introduction
2.3 Materials and Methods
2.3.1 Ready-Meal Sampling
2.3.2 Determination of the Sodium Content by Atomic Absorption Spectrometry
2.3.3 Data Analysis
2.4 Results and Discussion
2.4.1 Nutritional Label Information
2.4.2 Contribution of Ready-Meals Surveyed in 2006 to an Irish Adults Salt Intake and RDA
2.4.3 Salt Reduction Progress – Comparisons of the Salt Content of Ready-Meals in 2006 and 2010
2.4.4 Conclusions

3.1 Abstract
3.2 Introduction
3.3 Methods
3.3.1 Questionnaire Design
3.3.2 Pilot Questionnaire
3.3.3 Questionnaire Administration
3.3.4 Analysis of Data
3.4 Results
3.4.1 Consumer Demographics
3.4.2 Salt Consumption
3.4.3 Ready-Meal Consumption
3.4.4 Conclusions
3.5.1 Salt Consumption…………………………………………………………65
3.5.2 Ready-Meal Consumption……………………………………………….68
3.6 Conclusion……………………………………………………………………70

4. Current Salt Reduction Strategies and Their Effect on Sensory Acceptability:
A Study with Reduced Salt Frozen Ready-Meals…………………………….72
4.1 Abstract………………………………………………………………………72
4.2 Introduction………………………………………………………………….73
4.3 Materials and Methods……………………………………………………….75
  4.3.1 Screening of Sensory Panellists………………………………………..75
  4.3.2 Sensory Analyses Methods Used………………………………………..75
    4.3.2.1 Paired Comparison Test………………………………………….76
    4.3.2.2 Triangle Test………………………………………………………..76
    4.3.2.3 Preference Test…………………………………………………….77
    4.3.2.4 Ranking Preference Test…………………………………………..77
    4.3.2.5 Acceptability Test………………………………………………….77
  4.3.3 Ready-Meal Sample Preparation……………………………………….78
  4.3.4 Preparation of Samples for Sensory Analyses…………………………80
  4.3.5 Salt Substitute Addition…………………………………………………81
  4.3.6 Determination of the Sodium Content by Atomic Absorption
    Spectrometry………………………………………………………………82
  4.3.7 Data Collection and Statistical Data Analyses…………………………82
4.4 Results and Discussion………………………………………………………..82
  4.4.1 Impact of Incremental Salt Content Changes on the Sensory Properties
    of Frozen Ready-Meals……………………………………………………82
    4.4.1.1 Chicken Curry…………………………………………………….82
    4.4.1.2 Chilli Con Carne…………………………………………………..84
    4.4.1.3 Lasagne……………………………………………………………86
  4.4.2 Effect of the Addition of Salt Substitutes/Flavour Enhancers on the
    Sensory Properties of Reduced Salt Frozen Ready-Meals………………..88
    4.4.2.1 Chicken Curry…………………………………………………….89
    4.4.2.2 Chilli Con Carne…………………………………………………..93
    4.4.2.3 Lasagne……………………………………………………………98
  4.4.3 Consumer Acceptability of Reformulated Reduced Salt Lasagne…..101
4.5 Conclusions

5. Impact of Salt Reduction on the Instrumental and Sensory Flavour Profile of Reduced Salt Chilled Ready-Meals

5.1 Abstract

5.2 Introduction

5.3 Materials and Methods

5.3.1 Ready-Meal Samples

5.3.2 Sample Preparation – Sensory Profiling

5.3.3 Sensory Profiling Analysis

5.3.4 Isolation of Volatile Compounds using Headspace Solid-Phase-Microextraction (SPME)

5.3.5 Volatile Profile Analysis

5.3.6 Analysis of Data

5.4 Results and Discussion

5.4.1 Assessor Statistics

5.4.2 Sensory Profiling

5.4.2.1 Cottage Pie

5.4.2.2 Chicken Supreme

5.4.2.3 Vegetable Soup

5.4.3 Volatile Analysis

5.4.3.1 Cottage Pie

5.4.3.2 Chicken Supreme

5.4.3.3 Vegetable Soup

5.4.4 Correlation of Sensory Profiling Data with Volatile Analysis Data

5.4.4.1 Cottage Pie

5.4.4.2 Chicken Supreme

5.4.4.3 Vegetable Soup

5.5 Conclusion
6. The Use of Herbs, Spices and Whey Proteins as Natural Salt Substitutes and their Effect on the Sensory Acceptability of Reduced Salt Chilled Ready-Meals

6.1 Abstract

6.2 Introduction

6.3 Materials and Methods

6.3.1 Ready-Meal Samples

6.3.2 Addition of Individual Herbs, Spices and Whey Proteins

6.3.3 Formulation and Addition of Herb and Spice Blends

6.3.4 Addition of Whey Proteins

6.3.5 Sensory Acceptability Test

6.3.6 Data Collection and Statistical Data Analyses

6.4 Results and Discussion

6.4.1 Effect of Salt Reduction on the Acceptability of Commercial Ready-Meals

6.4.2 Effect of Individual Herbs and Spices on the Acceptability of Reduced Salt Ready-Meals

6.4.3 Effect of Spice Blend Addition on the Acceptability of Reduced Salt Ready-Meals

6.4.4 Effect of Whey Protein Addition on the Acceptability of Reduced Salt Ready-Meals

6.5 Conclusion

7. The Influence of Salt Taste Threshold on Acceptability and Purchase Intent of Reformulated Reduced Salt Vegetable Soups

7.1 Abstract

7.2 Introduction

7.3 Materials and Methods
7.3.1 Vegetable Soup Samples and Preparation...........................................169
7.3.2 Sensory Analyses..............................................................................170
  7.3.2.1 Salt Taste Threshold Measurements..............................................170
  7.3.2.2 Consumer Acceptability Test...........................................................171
7.3.3 Data Collection and Statistical Analyses............................................172
7.4 Results and Discussion.........................................................................173
  7.4.1 Salt Detection and Recognition Thresholds.........................................173
  7.4.2 Acceptability of Vegetable Soup Samples..........................................174
  7.4.3 Purchase Intent of Vegetable Soup Samples........................................175
  7.4.4 Relationships between Salt Thresholds, Acceptability Scores and
      Purchase Intent Data............................................................................176
7.5 Conclusions..........................................................................................178

8. General Discussion and Conclusion.........................................................179

9. Recommendations to Industry.................................................................185

10. Bibliography............................................................................................189

11. Publications............................................................................................232
  11.1 List of Peer Reviewed Papers from Thesis..........................................232
  11.2 List of Other Publications from Thesis.................................................232
List of Tables

Table 1.1: Average Daily Salt Intakes for Children 0-14 years\(^1\) …………………..7

Table 2.1: Declared Sodium Content as Reported on Nutritional Label and Actual Sodium Contents as Measured by Atomic Absorption Spectrophotometer……………………………………………………….45

Table 2.2: Declared Concentration of Salt in Ready-Meals Surveyed in 2006 and 2010……………………………………………………………………...51

Table 3.1: Percentage of Sample Population Age Groups and Percentage of Age Groups Reported in the Irish Census 2006 Results…………………..58

Table 3.2: Demographic Data of Respondents (n=357)……………………………………59

Table 3.3: List of Foods Consumers were Asked to Rank\(^1\) in Order of Increasing Salt Content in their Actual Order and Perceived Order…………………61

Table 4.1: Ingredient Declaration of No Salt Curry Mix Used in the Manufacture of ‘Model’ Chicken Curry Ready-Meals………………………………………79

Table 4.2: Salt Substitutes/Flavour Enhancers Sourced for Incorporation into Chicken Curry, Chilli Con Carne and Lasagne Ready-Meals………………….….81

Table 4.3: Probability Levels Associated with Sensory Analyses of Chicken Curry Ready-Meals with Salt Levels of 0.2-1.5% (w/v)………………………………84

Table 4.4: Probability Levels Associated with Sensory Analyses of Chilli Con Carne Ready-Meals with Salt Levels of 0.4-1.5% (w/v)…………………………..85

Table 4.5: Probability Levels Associated with Sensory Analyses of Lasagne Ready-Meals with Salt Levels of 0.55-0.85% (w/v)……………………………………88
Table 4.6: Probability Levels Associated with Sensory Analyses of Chicken Curry Ready-Meals with 0.4% Added Salt Substitutes

Table 4.7: Probability Levels Associated with Sensory Analyses of Chilli Con Carne Ready-Meals with 0.5% Added Salt Substitutes

Table 4.8: Probability Levels Associated with Sensory Analyses of Lasagne Ready-Meals with 0.5% Added Salt Substitutes

Table 5.1: Ingredient Declaration for Ready-Meals under Investigation

Table 5.2: Sodium Content and Salt Equivalents for Regular and Reduced Salt Ready-Meals

Table 5.3: Sensory Profiling Attributes and Definitions in Their Order of Perception as Agreed upon by Panel Consensus for Cottage Pie Ready-Meals

Table 5.4: Sensory Profiling Attributes and Definitions in Their Order of Perception as Agreed upon by Panel Consensus for Chicken Supreme Ready-Meals

Table 5.5: Sensory Profiling Attributes and Definitions in Their Order of Perception as Agreed upon by Panel Consensus for Vegetable Soup Ready-Meals

Table 5.6: Procrustes Analysis of Variance (PANOVA) of Regular and Reduced Salt Vegetable Soup

Table 5.7: GPA Scaling Factors for Each Panel Member and Each Ready-Meal

Table 5.8: Peak Areas ($10^5$) and Percentage of Total Area of Headspace Volatile Compounds Identified in Regular and Reduced Salt Cottage Pie Ready-Meals
Table 5.9: Peak Areas ($x \times 10^6$) and Percentage of Total Area of Headspace Volatile Compounds Identified in Regular and Reduced Salt Chicken Supreme Ready-Meals

Table 5.10: Peak Areas ($x \times 10^6$) and Percentage of Total Area of Headspace Volatile Compounds Identified in Regular and Reduced Salt Vegetable Soup

Table 6.1: Combination Ratios of the Individual Herbs and Spices Used in the Formulation of Spice Blends for Each Ready-Meal
List of Figures

**Figure 1.1:** Rock Salts and a Single Crystal of Sodium Chloride (Weiss, 2011; Wikipedia, 2006a)……………………………………………………………………3

**Figure 1.2:** The Ionic Bonding of Sodium Chloride (Monziz de Sá, 2006)……………4

**Figure 1.3:** The Sodium Chloride Crystal Structure of Type FCC. This Arrangement is known as Cubic Close Packed (CCP). Light Blue = Na⁺ (Sodium Ion) Dark Green = Cl⁻ (Chlorine Ion) (Padleckas, 2005)…………………………4

**Figure 1.4:** The Sodium Chloride Crystal Structure (Sayfa, 2007)…………………………5

**Figure 1.5:** The Positive Association between Sodium Excretion and Systolic Blood Pressure (Intersalt Cooperative Research Group, 1988)………………10

**Figure 1.6:** The Relation of Salt Excretion of Salt Excretion to the Slope of the Rise in Systolic Blood Pressure with Age in 52 Centres in the INTERSALT Study (MacGregor and de Wardner, 2002; Originally Adapted from Intersalt Cooperative Research Group, 1988)…………………………11

**Figure 1.7:** Tongue, Papillae and Taste Bud (Jocob, 2008)……………………………14

**Figure 2.1:** Salt Content of Each Individual Ready-Meal Surveyed in 2006 (n=68)..49

**Figure 3.1:** What the Percentage of Respondents Considered to be the Recommended Dietary Allowance (RDA) of Salt for an Irish Adult…………………60

**Figure 3.2:** Frequency Distribution (%) of Respondents who Consult Salt/Sodium Contents on Food Labels and the Percentage of Respondents who said these Salt/Sodium Contents Affect their Food Buying Choice………62

**Figure 3.3:** Percentage of Respondents who Consider Ready-Meals to be High in Salt/Sodium……………………………………………………………………63

**Figure 3.4:** Percentage of Consumers who Consider Ready-Meals to be a Healthy Food Option……………………………………………………………………65
Figure 4.1: Rank Totals (Based on Sum of Rank) for Ranking Preference Test of Regular Salt Chicken Curry (0.6%) and All Substitutes Incorporated at a Concentration of 0.4% into Reduced Salt (0.2%) Chicken Curry Ready-Meals (n=6; p<0.05)$^1$ .................................................................91

Figure 4.2: Rank Totals (Based on Sum of Rank) for Ranking Preference Test of Regular Salt Chilli Con Carne (1.0%) and All Substitutes Incorporated at a Concentration of 0.5% into Reduced Salt (0.5%) Chilli Con Carne Ready-Meals (n=6; p>0.05)$^1$ .................................................................96

Figure 4.3: Rank Totals (Based on Sum of Rank) for Ranking Preference Test of Regular Salt Lasagne (1.05%) and All Substitutes Incorporated at a Concentration of 0.5% into Reduced Salt (0.5%) Lasagne Ready-Meals (n=4; p>0.05)$^1$ .................................................................................100

Figure 4.4: Paired Comparisons and Acceptability Scores from a Consumer Acceptability Trial (n=175) Comparing Regular Salt Lasagne Ready-Meals with Reduced Salt KCL Ready-Meals.................................102

Figure 5.1: Sensory Profile (Mean Scores) for Cottage Pie Ready-Meals with Regular Salt (0.80g/100g) and Reduced Salt (0.35g/100g) Concentrations……..116

Figure 5.2: GPA Group Average Consensus Plot (Dimension 1 (79.71%) Vs Dimension 2 (5.93%)) for Cottage Pie Ready-Meals.........................117

Figure 5.3: Sensory Profile (Mean Scores) for Chicken Supreme Ready-Meals with Regular Salt (0.55g/100g) and Reduced Salt (0.33g/100g) Concentrations.................................................................119

Figure 5.4: GPA Group Average Consensus Plot (Dimension 1 (82.51%) Vs Dimension 2 (4.74%)) for Chicken Supreme Ready-Meals..............120

Figure 5.5: Sensory Profile (Mean Scores) for Vegetable Soup Ready-Meals with Regular Salt (0.93g/100g) and Reduced Salt (0.45g/100g) Concentrations.................................................................122
Figure 5.6: GPA Group Average Consensus Plot (Dimension 1 (81.19%) Vs Dimension 2 (5.10%) for Vegetable Soup Ready-Meals…………………..123

Figure 5.7: PLSR Correlation Loading Plot of the Relationship between Volatile Measurements (X-Variables) and Sensory Attributes (Y-Variables) in Cottage Pie Ready-Meals………………………………………………139

Figure 5.8: PLSR Correlation Loading Plot of the Relationship between Volatile Measurements (X-Variables) and Sensory Attributes (Y-Variables) in Chicken Supreme Ready-Meals………………………………………..141

Figure 5.9: PLSR Correlation Loading Plot of the Relationship between Volatile Measurements (X-Variables) and Sensory Attributes (Y-Variables) in Vegetable Soup Ready-Meals………………………………….………143

Figure 6.1: Mean Acceptability Scores\(^1\) for All Regular and Reduced Salt Ready-Meals…………………………………………………………………...154

Figure 6.2: Mean Acceptability Scores\(^1\) for Reduced Salt Cottage Pie Ready-Meals with Added Individual Herbs and Spices at Four Different Concentrations………………………………………………………….156

Figure 6.3: Mean Acceptability Scores\(^1\) for Reduced Salt Chicken Supreme Ready-Meals with Added Individual Herbs and Spices at Four Different Concentrations………………………………………………………….157

Figure 6.4: Mean Acceptability Scores\(^1\) for Reduced Salt Vegetable Soup Ready-Meals with Added Individual Herbs and Spices at Four Different Concentrations………………………………………………………….158

Figure 6.5: Mean Acceptability Scores\(^1\) for Reduced Salt Cottage Pie Ready-Meals with 0.25% Added Spice Blends………………………………………..160

Figure 6.6: Mean Acceptability Scores\(^1\) for Reduced Salt Chicken Supreme Ready-Meals with 0.1% Added Spice Blends…………………………………..161

Figure 6.7: Mean Acceptability Scores\(^1\) for Reduced Salt Vegetable Soup Ready-Meals with 0.05% Added Spice Blends…………………………………..163
**Figure 6.8:** Mean Acceptability Scores\(^1\) for All Three Reduced Salt Ready-Meals with Whey Proteins Added at Four Different Concentrations..........164

**Figure 7.1:** Mean Acceptability Scores\(^1\) of Regular and Reduced Salt Vegetable Soup Samples...........................................................................................................175

**Figure 7.2:** Mean Purchase Intent Scores\(^1\) of Regular and Reduced Salt Vegetable Soup Samples...........................................................................................................176
Abstract

The thesis was undertaken to determine the effect of salt reduction and the addition of salt substitutes/flavour enhancers on the sensory acceptability of commercial frozen and chilled ready-meals. High salt concentrations were found in a number of ready-meals sold commercially in Ireland. Despite adverse consumer attitudes to these products they remained a popular food choice with consumers. Sensory analyses conducted to determine the effect of a number of salt reduction strategies on three frozen ready-meals found that salt levels in chicken curry ready-meals could be reduced by 33%, by 50% in chilli con carne ready-meals and by 29% in lasagne ready-meals. The addition of commercially available salt substitutes or flavour enhancers into these meals allowed further salt reductions ranging from 48 to 66%. The impact of salt reductions on the sensory characteristics and volatile composition of three chilled ready-meals was determined using flavor profile descriptive sensory analysis coupled with solid-phase microextraction (SPME) and gas chromatography mass spectrometry (GC-MS) instrumental analysis. This approach identified several significant flavour/textural differences as affected by salt reductions. Reformulation by addition of selected spice blends into reduced salt cottage pie and chicken supreme ready-meals resulted in acceptability scores comparable to commercial regular salt counterparts. Finally, reformulation of reduced salt vegetable soup with added whey protein (lactoferrin) hydrolysate or rosemary significantly increased acceptability over its commercial regular salt counterpart. Interestingly, salt taste detection and recognition thresholds had no significant effect (p>0.05) on consumer acceptability or purchase intent of a series of regular and reduced salt vegetable soups. Overall, this thesis provided a detailed insight into the sensory aspects of reformulation strategies for salt reduction in frozen and chilled ready-meals.
Chapter 1
1. Literature Review

1.1 Introduction
Salt or sodium chloride, a substance essential for life processes, is the second most used food additive (Reddy and Marth, 1991) in the world today. It has been referred to as the fifth element, as vital as air, water, fire and earth (Dickinson, 1980). Similar to all other mammals, humans once consumed less than 0.25 grams of salt per day, however, consumption levels slowly increased with the discovery by the Chinese approximately 5000 years ago that salt could be used to preserve foods (He and MacGregor, 2010; Perry et al., 2010; Durack et al., 2008). This new found preservative aspect of salt addition helped to eliminate reliance on the seasonal availability of food and allowed for the exploration of foreign lands, ultimately resulting in the establishment of settled communities. Consequently, salt and salt deposits became a key factor in economic, religious, social and political development throughout history. Roman soldiers were once partially paid with salt; indeed, the English word ‘salary’ was derived from ‘salarius’ or allowance of salt (Binkerd and Kolari, 1975; Fregly, 1980). As salt and salt deposits were difficult to obtain, it became a highly valued trade item throughout history and was once worth its weight in gold, traded ounce for ounce where it was scarce (Fregly, 1980). This lack of salt helped defeat Napoleon and civil war battles raged over salt deposits (Dickinson, 1980; Reddy and Marth, 1991). Salt was also one of the first medicines for humankind. Ancient Egyptians (1600 B.C.) recommended salt for the treatment of an infected chest wound (Wormer, 1999) and over 2000 years ago, Greek medicine discovered topical use of salt for skin lesions, drinking salty waters for digestive troubles and inhaling salt for respiratory diseases (Wormer, 1999).

In recent times, the development and introduction of the refrigerator and the deep freezer to homes worldwide meant salt was no longer the primary preservative agent (Perry et al., 2010), however, it remained in food formulations due to the familiarity of consumers with the taste and flavours associated with salt preservation addition levels. Today, salt is still routinely added to foods to aid the manufacturing process of several processed convenience foods, such as frozen and chilled prepared
ready-meals. The demand for these convenience-based processed foods has soared in recent years and as a result ready prepared meals have become increasingly popular; however, evidence indicates that these meals can contain high levels of salt (FSA, 2003). Health agencies throughout the world are growing increasingly concerned with this high intake of non-discretionary sodium from salt and sodium containing additives used in the manufacture of these meals. Evidence now suggests that high dietary sodium intake, consumed primarily in the form of sodium chloride, is an important causal factor in the rise in blood pressure with age in industrialised countries such as Ireland, UK and USA (Intersalt Cooperative Research Group, 1988; Law, 1997, FSAI Scientific Committee, 2005). Previous attempts to reduce sodium intake through sodium restricted diets have shown short term success. However, these reduction studies have lacked long term sustainability and practicality for large populations due to the high levels of sodium in processed foods and the significant contribution these processed foods now make to our diet (James et al., 1987; Hooper et al., 2002). Additionally, numerous consumers perceive these salt/sodium restricted diets to be bland and tasteless while many low salt or sodium foods are considered to be unpalatable and unpleasant (Walsh, 2007). Therefore, maintaining the flavour and taste of the original salted product is one of the key challenges facing the industry as they strive to formulate reduced salt foods (Bertino et al., 1981).

1.2 Salt Production

The production of common salt is one of the most ancient and widely distributed industries in the world. Salt is naturally present in seawater and in rock salt deposits. All natural, underground rock salt deposits originate from early oceans which evaporated due to the heat of the sun (Durack et al., 2008). Over many millions of years, other sediments were deposited above the salt, leaving beds of rock salt below the surface. These deposits are the basis for the production of dry salt and salt in brine today. Dry salt is produced by the mechanical evaporation of solution mined brine from halite deposits (brine walls), solar evaporation of seawater or natural brine, and by underground mining of the mineral halite (rock salt) (Anonymous, 2007a). Solar evaporation is widely used in Asia, Africa, Australia and South America while salt mining is used in Europe and North America (Anonymous, 2007a).
1.3 Chemistry of Salt – Sodium Chloride

The classical definition of a salt is any ionic compound composed of cations, positively charged ions and anions, negatively charged ions so that the product is neutral and without a net charge (Brown et al., 2000). Sodium chloride, also known as table salt, edible salt or halite, is a crystalline white solid compound (Figure 1.1) consisting of two elemental substances, cationic sodium ($\text{Na}^+$) and anionic chloride ($\text{Cl}^-$), which react to form a halide salt called sodium chloride (NaCl) (Reddy and Marth, 1991). The elemental composition of sodium chloride was discovered at the turn of the 19th century (Reddy and Marth, 1991) and was found to contain 60.663% chlorine (Cl) and 39.332% sodium (Na) (Anonymous, 2007b).

Figure 1.1: Rock Salts and a Single Crystal of Sodium Chloride (Weiss, 2011; Wikipedia, 2006a).

The bonding of sodium and chlorine atoms is one of the classical examples of ionic bonding. When atoms of chlorine and sodium collide, the chlorine atom strips away the outer electron of sodium. This results in sodium having a positive charge and chlorine having a negative charge. The two ions of opposite charge attract each other and when this attraction holds them together an ionic bond is formed (Figure 1.2).
These ionic bonds form sodium chloride crystals with cubic symmetry (Figure 1.3) and the crystals consist of a repeating lattice of sodium and chloride ions. The larger chloride ions are arranged in a cubic close-packed structure, while the smaller sodium ions fill the octahedral gaps between them. It can be represented as a face-centered cubic (FCC) lattice with a two atom basis or as two interpenetrating face centered cubic lattices.

Within the cubic lattice each sodium atom has six chloride neighbours and each chloride atom has six sodium neighbours, as seen in Figure 1.4 (White, 2007). The larger anions (Cl\(^{-}\)) usually account for 74% of the space while the smaller cations (Na\(^{+}\)) make up the remaining 26% (Gilbert et al., 2003).
1.4 Physiological Role of Sodium Chloride in the body, Recommended Intake and Current Consumption Trends

Salt as separate ions of sodium and chloride play vital roles in human health. Sodium is an essential nutrient in our diet; an element the body cannot manufacture itself and accounts for approximately 2% of the human body’s mineral matter (Reddy and Marth, 1991). Approximately 50% of the sodium in the body is located in extracellular body fluids, 10% inside cells and 40% in the bones (Reddy and Marth, 1991). The osmotic pressure of the extracellular fluids in the body is controlled 90% by sodium ions (McCaughey and Scott, 1998; Dötsch et al., 2009), thus a precise equilibrium of sodium in every part of the body is crucial. A tight regulation of sodium levels in blood plasma and interstitial fluids is vital for basic physiological functions of practically all cells in the body, as numerous transport processes are dependent upon it and the smallest of deviations can affect the electrical activity of muscle and nerve cells, renal function, capillary exchange and cardiac output (Dötsch et al., 2009). One of sodium’s main functions in the body is to maintain the proper balance of fluids (IFST, 2003). This preservation of the delicate balance of bodily fluids is of vital importance and thus, makes sodium a key component in regulating blood volume and pressure (IFIC, 2005). When dissolved in bodily fluids sodium possesses a mild electrical charge (IFIC, 2005) and hence, acts to regulate the electrical charges moving in and out of cells. As a result of its electrical charge...
sodium is therefore essential in the transmission of nerve impulses around the body (IFIC, 2005). The neural control of muscle contraction including the largest and most important muscle, the heart, depends on signals generated by these electrolytes (IFIC, 2005; Higdon, 2004). Absorption of sodium in the small intestine plays an important role in the uptake and absorption of nutrients such as chloride, amino acids, glucose and water (BNF, 2004; Higdon, 2004). Chloride is also of vital importance for good health. It helps preserve the acid-base balance in the body and aids in potassium absorption (IFIC, 2005). It supplies the essence of hydrochloric acid in the gastric juices used in the stomach to help break down and digest food and in addition, controls the level of bacteria present in the stomach (Reddy and Marth, 1991; Higdon, 2004). It also enhances the ability of the blood to carry carbon dioxide from respiring tissues back to the lungs where it is exhaled from the body (IFIC, 2005).

In 1991 the UK Committee on the Medical Aspects of Food and Nutrition Policy (COMA) set the reference nutrient intake (RNI) value for sodium at 1.6grams(g)/70mmol, the equivalent of 4g of salt per day, to meet the needs of 97.5% of the population (SACN, 2003). This was subsequently endorsed by the UK Scientific Advisory Committee on Nutrition (SACN) which succeeded COMA in 2003 (SACN, 2003). However, SACN further recommended a target salt intake of 6g per day for the adult population to alleviate the burden of high salt consumption on the population’s health (SACN, 2003). The Food Standards Agency (FSA) in the UK and the Institute of Medicine’s (IOM) National Academy of Science in the USA further reiterated these recommendations by endorsing a similar upper level of no higher than 2.4g/100mmol of sodium, equivalent to 6g of salt per day (FSAI Scientific Committee, 2005). The US and Canadian panel on ‘Dietary Reference Intakes for Electrolytes and Water’ suggested an ‘adequate intake’ of 3.8g of salt per day and a ‘tolerable upper limit’ of 5.8g of salt a day (Institute of Medicine, 2005; Perry et al., 2010). While the World Health Organisation (WHO) has set a lower target for dietary salt intake at 5g per day (WHO, 2008; Perry et al., 2010). The distinction between recommendations of RNI values, adequate intakes, tolerable upper limits and target intakes for salt and the varying different values associated with these recommendations are a potential source of confusion for both consumers and industry personnel alike. In this regard The Food Safety Authority of Ireland (FSAI) in agreement with other institutes recommends an upper intake level of no higher than
6g of salt per day (FSAI Scientific Committee, 2005; Desmond, 2006) as an “achievable” target for the Irish population. However, the FSAI also state that “while six g/day is considered to be an achievable goal for the population at this time, it should not be regarded as an optimal or ideal level of consumption”. The FSAI Scientific Committee therefore recommend a daily allowance (RDA, equivalent to RNI) of salt for adults in Ireland to be 4g per day (1.6g/70mmol sodium) (FSAI, 2006). Salt intake in children needs to be proportionally lower than that of adults based on body weight. The RNI values previously agreed by COMA (1991) for infants and children were accepted and used by SACN in 2003 as a basis to set average daily salt intakes (Table 1.1). In Ireland the FSAI Scientific Committee (2005) endorses the recommendations set out in Table 1.1.

<table>
<thead>
<tr>
<th>Child Age</th>
<th>RDA Salt²</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-6 months</td>
<td>&lt;1g</td>
</tr>
<tr>
<td>7-12 months</td>
<td>1g</td>
</tr>
<tr>
<td>1-3 years</td>
<td>2g</td>
</tr>
<tr>
<td>4-6 years</td>
<td>3g</td>
</tr>
<tr>
<td>7-10 years</td>
<td>5g</td>
</tr>
<tr>
<td>11-14 years</td>
<td>6g</td>
</tr>
</tbody>
</table>

1 Adapted from FSAI Scientific Committee, 2005.
2 RDA=Recommended Dietary Allowance.

Current salt consumption levels worldwide exceed all RDA, RNI and target intake levels set by global organisations. This is attributed to the fact that approximately 75% of the salt in our diet comes from processed convenience foods; a further 10-15% is said to come from salt added in the home during cooking or at the table via the salt cellar and only approximately 5% occurs naturally as sodium in foods (IHF, 2004). Humans are genetically programmed to require a salt intake of less than 0.25g/day (He and MacGregor, 2010). Significant variations in salt intake levels have been reported worldwide and average intakes now fall between 9g and 12g per day, with many Asian countries having mean intakes well in excess of 12g.
per day (He and MacGregor, 2010). Globally, intake levels range from 0.2g per day in the ‘no salt’ culture of the Yanomamo Indians in Brazil (Oliver et al., 1975) to 12 plus grams per day in Japan (Perry et al., 2010). Among the 52 population samples included in INTERSALT study mean sodium values >200 mmol/day (~11g salt) in men were found in Canada, Columbia, Hungary, Ladakh (India), Bassiano (Italy), Poland, Portugal and South Korea (Rose and Stamler, 1989). In the UK overall mean weighted salt intake has been reported at 8.7g/day, with higher intakes for men (9.7g/day) compared with women (7.7g/day) (Craig et al., 2008; Perry et al., 2010). Breaking the UK down into its individual countries, England reported mean salt intakes of 9g/day in 2006 (Joint Health Survey Unit, 2006), in 2007 Wales and Scotland reported mean salt intakes of 8.1g/day and 9.1g/day, respectively (Joint Health Survey Unit, 2007a and 2007b). All three countries reported higher salt intakes among men in comparison to women. In Finland salt intakes as high as 14g per day were reported back in 1972, with a lower yet still high level of 9g per day in 2002 (Karppanen and Mervaala, 2006; He et al., 2010). In young Swedish men aged between 18 and 20 years salt intakes were estimated from 24 hour urinary sodium excretion levels at 11.5g of salt per day (Hulthén et al., 2010). In Ireland salt intake levels were first reported in 1980 by Connolly et al. who used a three day food diary to determine mean estimates to equal 8.9g/day. Three years later Madden et al. reported mean salt intakes of approximately 10g/day among Irish students, and found large differences between men and women’s consumption levels, which were reported as 12.2g/day and 7.9g/day, respectively. Short et al. (1987) collected 24 hour urine samples and reported intakes levels of 9.7g/day in men and 7.8g/day in women. More recently Harrington et al. (2008) reported mean estimated salt intakes in the SLÁN 2007 survey on dietary habits of the Irish population to be equal to 8.7g/day in men and 8.0g/day in women. However, these estimates are based on food consumption diaries and exclude discretionary salt added at the table via the salt cellar or during cooking. Taking this into account and the fact that today approximately 10-15% of total dietary salt intake is attributed to discretionary salt; actual estimated salt intakes in Ireland could be closer to 10g/day (Perry et al., 2010).
1.5 Health Risks Associated with Over Consumption of Salt

Throughout the past decade, high sodium levels in the diet have become a major worldwide health issue. The key concern is the association of the sodium electrolyte with hypertension or high blood pressure. Blood pressure is defined as the force of blood pressing against the walls of the arteries as the heart pumps blood around the body and is measured in millimetres of mercury (mmHg) (SACN, 2003). The seventh report of the Joint National Committee (JNC VII) defined persons with blood pressure less than 120mmHg systolic or 80mmHg diastolic as ‘normal’ and those with blood pressure ≥140/90mmHg as ‘hypertensive’ (Chobanian et al., 2003). A new term of ‘prehypertensive’ was also introduced by the JNC VII, to identify those persons in whom early intervention by adoption of a healthy lifestyle could reduce blood pressure and refers to systolic reading ranging from 120 to 139 mmHg and a diastolic reading ranging from 80 to 89mmHg (Chobanian et al., 2003). As far back as the 18th century, the Chinese observed that a “hard pulse” indicating high blood pressure was linked with high salt consumption and associated this “hard pulse” with stroke incidence (MacGregor and de Wardener, 1998). However, it was not until the 1900’s that the Western world made the correlation between high salt intake and hypertension (Durack et al., 2008; MacGregor and de Wardener, 1998) and since then a substantial body of evidence has emerged to link high salt consumption with raised blood pressure. Dahl (1960) was one of the first to report a strong relationship between high salt intake and the occurrence of hypertension in an ecological study of five geographically diverse populations. Other authors verified these findings, however, the validity of these cross-population results were questioned due to unstandardized methods and the omission of data on potential confounding factors in addition to multiple social and environmental differences among populations (He and MacGregor, 2008). To this effect a standardized international study with over 10,000 subjects including men and women aged 20-59, in 52 different population groups in 32 countries was conducted and positive associations between urinary sodium excretion, a marker of salt intake, and blood pressure were observed within and between populations, as shown in Figure 1.5 (Intersalt Cooperative Research Group, 1988; Elliott et al., 1996).
Figure 1.5: The Positive Association between Sodium Excretion and Systolic Blood Pressure (Intersalt Cooperative Research Group, 1988).

Within populations, those with higher sodium excretion tended to have higher blood pressure (Intersalt Cooperative Research Group, 1988; Elliott et al., 1996). In addition, the study demonstrated that salt intake was an important causal factor in the rise in blood pressure with age in industrialised countries (Figure 1.6) (Intersalt Cooperative Research Group, 1988; Elliott et al., 1996).
The INTERSALT study included only four communities with low salt intakes i.e. less than 3g per day. However, several other studies in underdeveloped communities where salt intake is naturally low have also highlighted the importance of salt intake in the development of hypertension. A study involving the Yanomamo Indians on the Venezuela and Brazil border, who had a low salt intake of 0.5g per day were found to have average blood pressure as low as 96/61mmHg with no evidence of a rise in blood pressure with age or cardiovascular disease due to the low level of salt consumption (Oliver et al., 1975; Mancilha-Carvalho et al., 1989). A study involving two rural communities in Nigeria where all aspects of lifestyle and diet were similar with the exception of salt intake showed differences in both salt intake and blood pressure (He and MacGregor, 2010; Uzodike, 1993). In Iran the underdeveloped Qash’qai tribe who had access to ground salt deposits developed high blood pressure and saw a rise in blood pressure with age similar to that of developed industrialised communities (Page et al., 1981). In the Pacific Islands one underdeveloped
community who used seawater in their food had higher blood pressure than other communities in the same area which did not use seawater (Elliott et al., 1996). Another study involving children where a randomised controlled trial was conducted involving 500 newborn infants in the Netherlands, found that infants who were given formula milk and solids with reduced salt content had significantly lower blood pressure at 6 months of age relative to a control group on a standard infant diet (Hofman et al., 1983). In animal trials, studies with Chimpanzees where an increase in salt from their usual intake of 0.5g salt per day to a level between 9g-15g per day led to a substantial and reversible increase in blood pressure (Denton et al., 1995). A number of migration studies have also highlighted the link between high salt intake and raised blood pressure. One such migration study involving a rural tribe in Kenya found that on migration to an urban environment an increase in salt intake was observed which resulted in a rise in blood pressure (Poulter et al., 1990). The substantial body of evidence linking high salt intake and high blood pressure is now overwhelming and as a result a number of intervention studies and treatment trials have been conducted to highlight the effect that reducing salt can have on blood pressure and cardiovascular disease (CVD) rates. He and MacGregor (2002) reported the findings from a meta-analysis based on 17 trials of modest reductions in salt intake in hypertensives and 11 similar trials in normotensives. The median reduction in salt intake in the trials was approximately 5g per day and this was associated with an average fall in blood pressure of 4.96/2.73 mmHg in hypertensives and 2.03/0.97 mmHg in normotensives (He and MacGregor, 2002). The DASH study (dietary approaches to stop hypertension) in the USA is one of the more successful dietary intervention studies. The study was a carried out on 412 random individuals using two diets, the first a typical American control diet and the second a diet rich in fruits, vegetables and low fat dairy products (Sacks et al., 2001; Vollmer et al., 2001). The study demonstrated a clear dose response with substantial falls in blood pressure associated with reduced salt intake in both hypertensives and normotensives. The DASH diet in combination with low sodium intake led to a mean reduction in systolic blood pressure of 7.1mmHg in normotensives and 11.5mmHg in hypertensives (Sacks et al., 2001; Vollmer et al., 2001). Raised blood pressure from a systolic pressure above 115 mmHg is one of the most significant direct causes of cardiovascular disease (Lewington et al., 2002), accounting for 62% of all strokes and approximately 50% of all heart disease worldwide (World Health Organization, 2003). Strazzullo et
al. (2009) reported the findings of a meta-analysis based on 13 trials which included 177,025 participants and over 10,000 vascular events and found a 23% greater risk of stroke for an average difference in sodium intake of approximately 5g of salt per day, and a smaller significant increased risk of coronary heart disease. In Ireland CVD is now the single highest cause of death accounting for over two in five of all deaths (FSAI Scientific Committee, 2005). According to the Irish Heart Foundation (IHF) each year in Ireland approximately 10,000 people die from cardiovascular disease - including coronary heart disease (CHD) and stroke (IHF, 2004). It is estimated that an average reduction in blood pressure as reported by He and MacGregor (2002) in the general population of most western countries would reduce the incidences of stroke by 24% and the incidence of ischemic heart disease by 18% (FSAI Scientific Committee, 2005). This would lead to a reduction in stroke deaths of approximately 600 per year in Ireland, with a similar reduction in the number of non-fatal disabling strokes, and a reduction in deaths from ischemic heart disease of approximately 1,100 per year (FSAI Scientific Committee, 2005).

On a worldwide scale Bibbins-Domingo et al. (2010) projected that reducing dietary salt intake by 3g per day in the USA would reduce the annual number of new cases of CHD by 60,000, stroke by 32,000 and myocardial infarctions by 54,000. They further stated that a regulatory intervention designed to achieve a reduction in salt intake of 3g per day would save 194,000 quality-adjusted life-years and $10 billion in health care costs annually (Bibbins-Domingo et al., 2010). Increased sodium/salt intake has also been linked to instances of stomach cancer (Forman et al., 1991; Joossens et al., 1996; Wong et al., 2004), asthma (Burney, 1987; Carey et al., 1993), osteoporosis (Matkovic et al., 1995; Lin et al., 2003), oedema (MacGregor and De Wardener, 1997), kidney disease including kidney (renal) stones (Du Calier et al., 2002; Verhave et al., 2004; He et al., 2009; Borghi et al., 2002; Cappuccio et al., 2000), Ménières disease (Beard, 2006) and diabetes (Ogihara et al., 2003; Hu et al., 2005) and is also indirectly a key influencing factor in several cases of obesity worldwide (He et al., 2008).
1.6 Salt Taste Receptor Interaction
The responsibility for detecting sodium in the body is assumed by the taste system. Up to 10,000 taste cells are located on the surface of the tongue, palate, epiglottis and pharynx (Plattig, 1984). On the tongue these taste receptor cells are clustered together in protuberances called papillae which take three forms circumvallate, foliate and fungiform; while those not located on the tongue are collected in stratified epithelia as shown in Figure 1.7 (McCaughey and Scott, 1998).

Figure 1.7: Tongue, Papillae and Taste Bud (Jacob, 2008).

Circumvallate papillae are sunken papillae which have channels separating them from the surrounding wall. The taste buds found in the papillae are arranged in layers within these channels and confer sour/bitter sensitivity to the back of the tongue which is innervated by the glossopharyngeal (IX) nerve (Jacob, 2008). Foliate papillae are situated on the edges of the tongue slightly in front of the circumvallate line. They are predominantly sensitive to sour tastes and are also innervated by the glossopharyngeal (IX) nerve (Jacob, 2008). Fungiform papillae are located on the front part of the tongue. They are innervated by the chorda tympani branch of the facial (VII) nerve and appear as red spots on the tongue (Jacob, 2008). These taste buds consist of small hairs called microvilli that lie in the taste pore where dissolved food or drink binds to a receptor and the taste cell then sends a signal to the brain.
telling it that this morsel is sweet, sour, bitter, salt or savoury (Plattig, 1984). At the base of each taste bud are basal cells that evolve to replace taste receptor cells as they die and act to completely renew the entire gustatory receptor system every fourteen days (McCaughey and Scott, 1998). At the basal end taste cells form synapses with the peripheral axons that serve gustation and between them tight junctions are formed that strictly limit access of molecules into the intercellular space (McCaughey and Scott, 1998). Animals including mammals have evolved dedicated salt sensing systems (Lindemann, 2001). Salt taste transduction is known to occur via ion channels located in the microvillus cell membrane of taste receptor cells in our taste buds (Dötsch et al., 2009). Salt sensitive receptors are essential for the acceptance of low salt concentrations of sodium and thus help satisfy ‘salt appetite’, while simultaneously serving as a warning mechanism against hyper-salinity and therefore, help to maintain ion and water homeostasis (Chandrashekar et al., 2010). As such, salt taste triggers two distinct behavioural responses in mammals. In mice, a low concentration of salt initiates the acquisition of large amounts of sodium through the creation of a ‘sodium appetite’ (McCaughey and Scott, 1998). This salt-taste pathway has three salient properties in that it is highly selective for sodium versus other cations, it is activated at salt concentrations as low as 10mM and is blocked by lingual application of the ion-channel inhibitor amiloride (Heck et al., 1984; Ninomiya, 1998; Hettinger and Frank, 1990; Yoshida et al., 2009; Chandrashekar et al., 2010). In contrast, receptor cells that are only activated by high concentrations of salt start to become significant only at concentrations greater than 150mM salt, are unaffected by the presence of amiloride and also respond to a wide range of non-sodium salts (Ninomiya, 1998; Hettinger and Frank, 1990; Yoshida et al., 2009; Chandrashekar et al., 2010). Amiloride is an inhibitor of the epithelial sodium channel (ENaC), a potential component of the salt taste system. The ENaC channel is made up of three subunits, α, β and γ, and has a central role in regulating trans-epithelial transport of sodium in a wide range of bodily tissues including the kidneys, airway cells of the lungs, epithelial skin cells and the ducts of salivary and sweat glands (Canessa et al., 1994; Hummler and Beermann, 2000; Chandrashekar et al., 2010). Chandrashekar et al. (2010) recently confirmed that taste responses to salts are mediated by two genetically distinct components and validated ENaC as the taste receptor responsible for behavioural acceptance of, and attraction to, sodium chloride. The authors genetically engineered mice lacking the ENaCα (channel subunit) in taste receptor
cells and produced animals exhibiting a complete loss of salt attraction and sodium taste responses. They found that mice lacking the ENaCα showed a complete loss of response to low sodium concentrations in comparison to control wild mice which had not been genetically engineered however, all other tastes i.e. sweet, sour, bitter and umami, were unaffected (Chandrashekar et al., 2010). This study also identified a second distinct set of taste buds contained in fungiform and the palate which possessed the sour cell marker, Car4, and ENaCα. When mice were genetically engineered without the ENaCα in these specific taste receptor cells in the fungiform and palate taste buds, the mice had normal responses to varying salt concentrations indistinguishable from the control wild mice thus demonstrating that the ENaCα expression in sour cells is not required for salt taste (Chandrashekar et al., 2010).

Physiological experiments in non-human primates have clearly illustrated an amiloride-sensitive element in taste responses to stimuli (Hellekant and Ninomiya, 1994; Hellekant et al., 1997). However, psychophysical research in humans remains inconclusive (Halpern 1998); with some studies suggesting amiloride may alter salt taste (Schiffman et al., 1983; Halpern, 1998). However, given the molecular resemblance between mice and human beings for all other basic tastes (Yarmolinsky et al., 2009), a ‘human’ specific molecular mechanism is unlikely and the findings of Chandrashekar et al. (2010) may hold true.

1.7 Functions of Salt in Food

Salt the second most-used food additive today (Reddy and Marth, 1991), is a valuable commodity used extensively in food processing (Gibson et al., 2000). It is a versatile product with a diverse range of functions within food which can be separated into three major roles; preservation, sensory and processing.

Salt is an important natural preservative and has been used for centuries to preserve products such as meat, fish and dairy products. Regular table salt alone does not exhibit antimicrobial properties, however, its ability to reduce water activity ($a_w$) in food can slow down or disrupt vital microbial processes (Albarracin et al., 2011). $A_w$ is the ratio of the vapour pressure of water in a food to the vapour pressure of pure water at the same temperature and is essentially a gauge of the availability of water for enzymatic reactions, microbial growth and metabolism (Durack et al., 2008).
High salt concentrations produce changes in cellular metabolism due to its effect on osmotic pressure (Albarracín et al., 2011) and as a result bacterial cells experience osmotic shock and plasmolysis, loose turgor ultimately leading to either termination of growth, dormancy or death (Durack et al., 2008). In inhibiting microbial growth, salt interacts with both the acidity (pH) of the medium and its temperature as well as other factors such as ingredients which are unique to different foods (Hutton, 2002). Typically at a\textsubscript{w} values below approximately 0.500 no microbial growth is observed (Durack et al., 2008). In processed meats salt functions as a preservative by reducing a\textsubscript{w} thus restricting bacterial growth and together with nitrite acts to inhibit growth of \textit{Clostridium botulinum} (Reddy and Marth, 1991; IFIC, 2005). In natural cheeses salt retards growth of undesirable bacteria such as yeasts and moulds and helps ensure predominance of the desired flora (Reddy and Marth, 1991). In pasteurized process cheeses and shelf-stable products which are not commercially sterile, salt plays a critical role in combination with a\textsubscript{w}, pH and moisture in preventing outgrowth of \textit{C. botulinum} (Reddy and Marth, 1991; IFIC, 2005). In salad dressings salt along with acidic ingredients prevent the growth of spoilage bacteria, yeasts and moulds (IFIC, 2005). In fermented foods such as pickles and sauerkraut, salt suppresses the growth of spoilage organisms while allowing the lactic acid bacteria to produce acid. This increased acidity contributes to the flavour and helps limit further microbial growth (IFIC, 2005; Reddy and Marth, 1991). Salt is a significant factor in the preservation of smoked fish. Non-smoked, salted fish such as cod and herring are preserved by a combination of direct microbial inhibition, enzyme inhibition and a significant dehydration of the fish tissue (Hutton, 2002).

Saltiness is one of the basic tastes along with sweet, sour, bitter and umami (IFIC, 2005). Classic salty taste is said to be imparted by lithium chloride (LiCl), however this salt is also said to have a bitter component (Man, 2007; Reddy and Marth, 1991). Therefore, unlike the other basic tastes which have many triggers, only sodium chloride is associated with the truly unique taste of saltiness. Sodium chloride is added to numerous processed foods for its specific taste properties and also for its ability to enhance or modify the flavour of other ingredients within food (Hutton, 2002). The precise influence of this salt is very product specific, as the overall flavour of any particular product is affected by both the chemical nature of the ingredients, their texture and the levels of salt used (Hutton, 2002). In addition to the
salty or saline taste that sodium chloride produces, expert panels have reported that low levels of salt in solution also give a sensation of sweetness (Kuntz, 1994). Gillette (1985) found that the addition of salt into tomato, split pea and beef soups enhanced the perception of sweetness more than the perception of saltiness. Salt and other sodium containing compounds have also been shown to reduce the sensation of bitterness (Breslin and Beauchamp, 1995; Hutton, 2002). It has been reported that in many products metallic/chemical off-notes are decreased or masked by the addition of sodium chloride while saltiness remains unaffected (Kilcast and den Ridder, 2007). The flavour enhancing effect of salt is thought to be related to its effect on water activity. Salt acts to “tie-up” some of the free water molecules in food thus increasing the concentration of flavour molecules in solution and enhancing their volatility (Hutton, 2002). As salt affects the way other flavours are perceived it is often added to food products to balance out flavour (Kuntz, 1994). Gillette (1985) found that the most significant effect sodium chloride had on various foods was its ability to improve the flavour balance. Flavour balance in various foods was found to be “smoothed”, “rounded out” and “fuller” (Gillette, 1985). Saltiness is the predominant flavour note in a range of snack foods such as crisps and popcorn, and is often the only recognisable taste. However, in these foods salt also offers a convenient vehicle for uniformly distributing other flavour components, in addition to vitamins, antioxidants and other micronutrients, throughout the finished product (Hutton, 2002). In dry foods such as crackers and pretzels, salt helps to decrease the perception of dryness these products generate in the mouth (Hutton, 2002; IFIC, 2005). Salt has also been found to increase the perception of fullness and thickness giving the impression of less watery products (Gillette, 1985). The amount of salt added to a food is ultimately determined by the preferences of the consumer. Besides the effect of other ingredients and the type of product, consumers themselves can determine the acceptable sensory salt level (Kuntz, 1994). As people age they lose their taste and flavour acuity and products may require higher salt levels, on the other hand, those who have lowered their salt intake may find normal levels of saltiness excessive (Kuntz, 1994).

For years salt has been added to foods to both preserve and improve flavour. Today salt is also a vital ingredient in the production process of many foods as it is used as a binder, colour developer, texturiser and fermentation control agent
Salt can have a direct effect on other essential ingredients that are relevant to the production and nature of the final product. These effects are usually product and process specific. One of salt’s main roles in processed and comminuted meat products is the solubilization of myofibrillar protein (Desmond, 2006). The proteins that are extracted into solution effectively form a “cement” between individual pieces of meat. This “cement” binds the meat together and reduces cooking losses. In the raw state the meat becomes more sticky and cohesive; after cooking, a solid mass is produced (Hutton, 2002). Fat binding in highly comminuted meat products is increased by the addition of salt; the solubilized protein in meat forms a micelle around fat globules present hence retaining the fat (Monaghan and Troy, 1997; Desmond, 2006). In sausage making stable emulsions are formed when the salt soluble protein solutions coat finely formed globules of fat providing a binding gel consisting of meat, fat and moisture (SaltSense, 2006b). In coarser products such as burgers, the binding effects are reduced which results in a product which keeps its shape during cooking but maintains a crumbly, fibrous texture on eating (Hutton, 2002). Meat binding properties of salt are also used in the manufacture of reformed joints and steaks (Hutton, 2002). Salt also has a significant physical effect on the properties of wheat gluten making it more stable and less extensible; these properties are associated with a binding or tightening of dough during bread making, resulting in less sticky dough (Hutton, 2002). Salt is also added to food products to aid the development of colour in meats such as ham, bacon and hotdogs (Brandsma, 2006). Used with sugar and nitrate or nitrite, salt produces a colour in processed meats that consumers expect and like to see (IFIC, 2005). Nitrite added in these products reacts with the meat myoglobin to develop an initial colour change to red and subsequently to pink by first converting the myoglobin to nitrosomyoglobin (red) and upon heating this compound is then converted to nitrosohemochrome (pink) (Man, 2007). Salt also helps bread dough develop a golden colour on its outer crust via increased caramelisation and by reducing sugar destruction in the dough (Wing and Scott, 1999). As a texture aid, salt improves the tenderness of cured meats by promoting the binding of moisture by protein (IFIC, 2005; Desmond, 2006). In bread, salt strengthens the gluten in the dough, providing a consistent grain, texture and dough strength which allows the dough to rise without tearing (SaltSense, 2006b). During pickling of foods the concentration of salt brine is gradually increased helping to draw out moisture, producing a pickled food with a
crisp, firm texture (IFIC, 2005; Hutton, 2002). In cheese production salt develops the characteristic rind hardness and helps produce the even consistency in the cheese (SaltSense, 2006b). Addition of salt to bread dough controls the fermentation action of the yeast (IFIC, 2005). The role of salt in controlling fermentation of baked products is not only due to the increase in osmotic pressure, but also to specific actions of sodium and chloride on the semi-permeable membranes of yeast cells (Hutton, 2002). Increased salt levels reduce the rate of gas production and extend the proof time to maintain final loaf volume (Hutton, 2002). Salt is an important ingredient in the production of fermented vegetables as it specifically contributes to the precise fermentation conditions required for the final product (Hutton, 2002). Salt also controls the rate of lactic acid fermentation in cheese production (Reddy and Marth, 1991). Other functions of salt in food processing include soaking of fish prior to canning in 50-100% brine; this washes-out the insides of the fish, removes blood residues and most of any broken gut (Hutton, 2002). Adding a pinch of salt to cream or egg whites before they are whipped helps increase volume and serves as a stabilizer (IFIC, 2005). In batters, salt addition helps prevent batter freezing when applied to frozen products, thus facilitating crumb application (Hutton, 2002).

1.8 Salt Content of Processed Convenience Foods
Currently approximately 75% of an adult’s total dietary salt intake comes from processed convenience foods (IHF, 2004). In 2004 the National Diet and Nutrition Survey in the UK conducted an investigation into the foods which contributed significantly to excess salt intake and discovered that foods such as cereals and cereal products accounted for 35% of mean intake, meat and meat products accounted for 26% with all other food groups accounting for less than 10% of the daily mean intake (Hoare, 2004). Within these groupings they reported that by itself white bread made up 14% of mean daily intakes, breakfast cereals accounted for approximately 5% and biscuits, buns, cakes and pastries combined made up 4% of mean intakes (Hoare, 2004). In Ireland, Perry et al. (2010) reported similar findings to those in the UK with cereals, breads and potatoes contributing 34% to overall salt intake and meat, fish and poultry contributing 22% to overall salt intake. The study, based on a food frequency questionnaire, reported that soups, sauces and spreads made up 14% of overall salt intake in Ireland, vegetables contributed 11%, dairy products and fats made up 10%,
sweet and savoury snacks accounted for 8% and drinks made up the remaining 1%.

With regards to specific foods, Gibson et al. (2000) reported that pizza contained approximately 5.75g salt per serving. Webster et al. (2010) reported the sodium contents of numerous processed foods in Australia and found that per 100g serving white bread contained an average of 1.3g salt, savoury biscuits contained 1.9g salt, flavoured noodles contained 1.6g salt, packet pasta contained 2.3g salt, meat and meat products contained 2.1g salt, which included bacon at 3.1g salt, sausages and hot dogs at 2.1g salt and meat burgers at 1.2g salt, processed and hard cheeses contained an average of 3.5g and 1.8g respectively, while anchovies contained an alarming 14.0g salt per 100g. Another similar food survey in Australia revealed that breakfast cereals in the categories of sweet, low fibre and high fibre contained mean salt levels of 0.97g, 1.5g and 0.57g salt per 100g respectively (Grimes et al., 2008). The same survey reported regular butter and margarine had an average of 1.2g salt per 100g, meat pies and sausage rolls had an average of 1.2g salt per 100g, while tinned tuna had mean salt contents of 0.89g per 100g. In addition to these studies on specific or individual foods, Consensus Action on Salt and Health (CASH) identified that many popular 3 course meals eaten in UK high-street restaurants frequently contained over twice the daily maximum limit of salt for an adult (Consensus Action on Salt and Health, 2009). A separate CASH study revealed that a large full English breakfast consisting of two sausages, two rashers of bacon, one fried egg, mushrooms, baked beans, two slices of black pudding, a tomato and one slice of toast with butter contained in excess of 6g of salt with a smaller version of the same meal containing approximately 4.5g salt (Consensus Action on Salt and Health, 2008). Popular on-the-go breakfast snacks such as croissants, pastries and muffins were found to contain more salt than a rasher of bacon while a ‘healthy’ at home breakfast of coffee, orange juice, 30g cornflakes and 2 slices of toast with butter contained almost 50% of an adults daily maximum limit of 6g salt (Consensus Action on Salt and Health, 2008). Unfortunately, many consumers are often not aware of the amount of salt in the foods they consume on a regular basis. This fact combined with the data outline above highlights the need to formulate salt/sodium reduction strategies for the processed food sector.
1.9 Ready-Meals in Ireland and Their Reported Salt Content

The definition of the term ‘ready-meal’ generally refers to a prepared meal that requires little, if any, extra ingredients (Buckley et al., 2007), and includes meat, poultry, fish, seafood, pasta, rice and vegetable dishes, which can subsequently be classified as traditional, continental, ethnic, vegetarian or low calorie/healthy option dishes (Henchion, 2000). These products have had recipe ‘skills’ added to them by the manufacturer, resulting in a high degree of readiness, completion and consumer convenience. In the UK and Ireland, ready-meals are generally accepted to be complete meals that require few or no extra ingredients; however, in many European countries the term describes meal centres, a single meal component which often requires cooking with additional ingredients in order to complete a meal. Certain ready-meals require cooking in an oven or grill; while more commonly others simply need reheating in a microwave, prior to serving (Henchion, 2000; Buckley et al., 2007).

The prepared consumer foods sector, commonly referred to as the convenience food sector, is a significant component of the Irish economy. In 2001, just under half of the sectors’ total output was exported for a value of €841 million, representing a 12% annual increase on the previous year (de Boer et al., 2004). Part of this growth has been from the ever increasing demand for ready-meals. In Europe sales of ready-meals saw an annual growth rate of 2.5% between 2000 and 2006 increasing from a value of €9,098 billion to a value of €10.5 billion (Datamonitor, 2007). Frozen and chilled ready-meals combined accounted for 81% of these total sales (Datamonitor, 2007). In Ireland, the ready-meal sector saw upward movement of 4% in value terms in 2005, representing a marginal increase on the previous year’s rate of growth. Value sales which reached €176.6 million in 2005 were driven by strong ongoing growth in convenience food consumption, particularly through dinner mixes, the leading sub-sector in terms of value growth (Euromonitor, 2006). The current adverse economic conditions being experienced in many developed countries around the world has left food manufacturers and industry personnel worried about the future of their products. However, according to Euromonitor International (2010) demand for ready-meals in Ireland has held up strongly amidst the recessionary conditions of 2010. In 2010 retail volume and value growth rates for the sector exceeded those of 2009, with retail value and volume sales expected to grow at a compound annual
growth rate (CAGR) of 4% between 2010 and 2015 (Euromonitor International, 2010).

The ready-meal market can be loosely divided in two, the traditional frozen ready-meal sector and the rapidly growing chilled ready-meal sector. The strong demand from consumers for products that are convenient, fresh, healthy, safe-to-eat and of good quality has significantly contributed to the growth of the chilled ready-meal sector (Anonymous, 1994). These products are generally perceived to be fresher, healthier and of better quality than their frozen counterparts by consumers (Mitchell et al., 2011). However, frozen foods continue to offer advantages in terms of convenience and bulk buying, and are a long established item on consumers shopping lists. They also offer benefits in terms of health as they do not always contain the same levels and range of preservatives that are sometimes found in chilled produce (Anonymous, 2004b). As Irish consumers become more willing to experiment with international cuisines, ‘ethnic foods’ have become a firm favourite. With an estimated 175,000 foreign nationals living in Ireland today, the food of Eastern Europe, Africa, Asia and India (Fitzgibbon, 2006) have become more and more popular in Ireland which in turn, has lead to a rise in both the consumption of, and the demand for, ethnic ready-meals. Other factors behind the growth and development of the ready-meal market in Ireland include the demise of families sitting down to eat together, an increase in one and two-person households, a rise in freezer and microwave oven ownership and the ever increasing consumer demand for convenience foods (FSA, 2003). Today, amidst the economic downturn the ready-meal market in Ireland has continued to strive. Fears over job security has also resulted in many Irish people working longer hours and thus turning to convenience based foods such as ready-meals as an alternative time saving food option. Additionally, the decreased spending on social events such as eating out in restaurants and bars has also led to an increased demand for ready-meal products as they are now seen as a cheaper alternative to the dining out experience.

Back in 2000 Gibson et al. were among the first to report the levels of salt in a number of ready-meals in Northern Ireland. These products included chicken supreme with rice and chicken tikka masala with rice, both of which were reported to contain 1.75g of salt per serving (Gibson et al., 2000). In addition, the authors found
that both lasagne and cream of tomato soup contained 3.0g of salt per serving, equivalent to 50% of the UK target daily salt intake of 6g per day. A study of 69 ready-meal products carried out in 2003 by the Food Standards Agency (FSA) revealed that 83% of all standard ready-meals contained more than 40% of the UK’s target daily salt intake. One particular meal surveyed contained 5.9g of salt per portion corresponding to ~99% of the target daily salt intake for an adult (FSA, 2003). While the study found that ready-meals labelled as ‘healthy choice’ often contained less salt when compared to their standard salt counterparts, these differences were usually very small (FSA, 2003). In Australia in 2007, ten pre-prepared ready-meals categorized as ‘Italian/traditional/other with accompaniment’ were reported to contain an average of 277mg of sodium per 100g, equivalent to 0.69g of salt per 100g (Grimes et al., 2008). In 2008, Hopkins and Thomas reported the salt content in a number of ready-meals they found to be popular among elderly people in the UK. The study revealed that mean salt contents per serving accounted for between 40 and 43% of the recommended daily maximum (6g) in ready-meals such as chicken curry, lasagne, chilli con carne and cottage pie. In 2010, Webster et al. reported the mean sodium content among 265 soup samples in Australia as 304mg/100g, equivalent to 0.76g salt/100g. The same survey reported mean sodium values from a sample of 89 frozen ready-meals as 265mg/100g or 0.70g of salt/100g. A study conducted by Consensus Action on Salt and Health (CASH) in the UK highlighted particularly high levels of salt in many popular takeaway and ready-meals. One example from the study revealed a takeaway bought curry with all the extras such as rice, naan bread, sag aloo, poppadom and chutney, could contain as much as 20.5g salt, while data published on levels of salt in ready-meals revealed that many popular meals contained more than or at least 50% of the UK daily salt maximum of 6g a day (Consensus Action on Salt and Health, 2010). To date in Ireland only one such equivalent survey exists. In March 2011 safefood published the results of a survey of salt levels in soup in catering establishments on the island of Ireland. The report found that the average portion of soup (approximately 303g) contained 60% of the RDA of salt intake for an Irish adult and that one in ten of the samples contained more salt than the entire RDA in a single serving (Safefood, 2011). Worryingly, no such survey exists for meat based ready-meals such as lasagnes and curries in Ireland. Given the high levels of salt previously reported in these products, in combination with their ever growing popularity, and the fact that the RDA of salt in Ireland is equivalent to 4g/day as
opposed to 6g/day, the contribution of these products to mean daily salt intakes of Irish adults may be highly significant.

1.10 Salt and Sodium Labelling of Foods

Within the EU, the placing of nutritional values on a product is optional according to the Council Directive 90/496/EEC of 24 September 1990 on nutrition labelling for foodstuffs (Przyrembel, 2004). However, as stated in Article 4 of Directive 90/496/EEC “where nutritional labelling is provided, the information to be given shall consist of either group 1 or group 2 in the following order: Group 1 (a) energy value; (b) the amount of protein, carbohydrate and fat. Group 2 (a) energy value (b) the amounts of protein, carbohydrates, sugars, fats, saturates, fibre and sodium. Where a nutritional claim is made for sugars, fats, saturates, fibre and sodium, the information to be given shall consist of group 2”. Therefore, under EU regulations there is no obligation on food manufacturers to declare the levels of either sodium or salt on food products nutrition label. However, when a claim regarding salt is made it must comply with regulations set out in regulation (EC) 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on food. Under this regulation claims that a food is ‘low in sodium/salt’ and any claim likely to have the same meaning to the consumer may only be made when a product contains no more than 0.12g of sodium, equivalent to 0.3g of salt per 100g or per 100ml. A claim that a food is ‘very low in sodium/salt’, and any similar claim likely to have the same meaning for the consumer, may only be made where the product contains no more than 0.04g of sodium, equivalent to 0.1g salt per 100g or per 100ml. A claim that a food is ‘sodium-free’ or ‘salt-free’, and any claim likely to have the same interpretation by the consumer, may only be made when a product contains no more than 0.005g of sodium, equivalent to 0.0125g salt per 100g. A claim stating that the content of either sodium or salt has been reduced, and any claim likely to have the same meaning for the consumer, can only be made where the reduction in content is at least 25% compared to a similar product.

In Ireland it is compulsory for pre-packed processed foods to contain a label which states the list of ingredients, along with other essential information such as the name under which the product is sold and net quantity to name but two (FSAI, 2007).
Nutritional labelling of sodium and salt on food products can be a source of much confusion for many consumers with actual levels of salt contained in the product extremely difficult to determine easily. Confusion over this matter is further added to by the variation in exactly how sodium and salt levels are reported. Many food products simply list grams of salt or sodium but do not inform the consumer if it is per 100g or per serving, others just list grams per 100g or alternatively grams per serving of sodium without any equivalent salt figures. Other manufacturers include all the nutritional information for both sodium and salt contents however; a select few do not provide labelling of any such information. These labelling variations are not only confusing but can lead consumers to misinterpret the information. Grimes et al., (2009) reported that 65% of consumers were unable to correctly identify the relationship between salt and sodium and found that 40% considered salt and sodium to be the same substance. Consumers who are simply not aware of the connection between sodium and salt may in fact read the sodium content on the food label and may not connect it with salt content and/or may believe it is the salt content. As a method of overcoming this confusion some manufacturers have now started to include guideline daily amount (GDA) information for salt in panels on the front of food products. This panel clearly states the amount of salt, in addition to calories, sugars, fat and saturates in grams per serving and additionally indicates the percent contribution each of these make to the adult GDA. In combination with this on front of pack display, the Food Standards Agency (FSA) in the UK have developed a "traffic light" labelling system which simply and easily informs the consumer whether a product contains high, medium or low concentrations of fat, saturated fat, sugars and salt. A red background colour indicates the product has a high level of the stated nutrient, an amber coloured label indicates medium levels and a green colour implies low levels (FSA, 2008). Currently, the European Commission (EC) does not support this system as they believe that consumers need to be further educated about the benefits of a balanced, healthy diet and therefore consider this method to ‘oversimplify’ dietary intakes (Durack et al., 2008). In Australasia, manufacturers pay for the privilege of displaying the healthy option logo, "Pick-the-Tick", which is only awarded if manufacturers meet the standards laid down by the National Heart Foundation (Sharp, 2004). This scheme has reportedly resulted in the removal of 33 tonnes of salt from food products in New Zealand in a single year (Ní Mhurchú and Gorton, 2007). The need to standardise salt/sodium labelling across the board is an
issue of high importance, and if introduced successfully will put further pressure on food manufacturers to lower the level of salt in their products, as consumers will be easily able to compare salt/sodium levels across products.

1.11 Approaches to Salt Reduction in Food and Their Effect on Sensory Properties

The sensory attributes of a food are one of the most important factors that influence consumer preference for one product over another. Preserving the taste and flavour of the original salted product is one of the major challenges facing the industry today as they endeavour to formulate reduced salt products (Gillette, 1985, Gibson et al., 2000) and is now recognised as one of the top 14 challenges facing the food industry (Katan et al., 2009). Consumers have grown accustomed to the taste associated with elevated salt contents in processed food and as a result the food industry is struggling to lower the concentration of salt while simultaneously maintaining sensory acceptability. Food manufacturers have adopted several different approaches in an effort to decrease the amount of salt in their foods. These approaches are commonly applied independently of each other; however, they can also be applied in combination to achieve higher levels of salt reduction (Kilcast and den Ridder, 2007).

1.11.1 Gradual Salt Reduction – Reduction by Stealth

To date, one of the most promising salt reduction strategies involves incremental reductions in the amount of salt added to food over an extended time period until the desired reduced salt level is reached. This popular approach often referred to as ‘reduction by stealth’ allows manufacturers to make stepwise salt reductions in the magnitude of 5-15% in food (Doyle, 2008; Durack et al., 2008). Evidence suggests that as the reductions are gradual there is no significant perceivable effect on sensory properties or product acceptability (Gibson et al., 2000; Dötsch et al., 2009) as consumers taste palates adjust to the revised sensory profile (Kilcast and den Ridder, 2007). Consequently, consumers salt taste receptors become much more sensitive and highly salted foods which were once seen as acceptable are now deemed unpleasant (Gibson et al., 2000). Food manufacturers are often wary of announcing the salt reduction achievements they have made or are attempting to make, believing that
publicity of such information may cause consumers to purchase a rival product, under
the preconceived assumption that low salt equals low taste. Instead many food
companies are quietly and gradually reducing salt levels unbeknownst to consumers.
Over a seven year period in the UK (1998-2005) salt reductions of approximately
33% have been achieved in cereals and since the late 1980’s reductions of 25% have
been achieved in bread (Kilcast and den Ridder, 2007; He and MacGregor, 2010).
The Heinz product range has had between 11-18% salt removed over the past number
of years (Kilcast and den Ridder, 2007). Between 2005 and 2006 Unilever removed
3000 tonnes of sodium from their product portfolio via reduction by stealth which
included; a 40% and 10% sodium reduction in pasta and sauce side dishes in Australia
and the USA, respectively, a 10% reduction in dry soups in Europe and 7% in Latin
America and 35-50% reduction in Pot Noodles in the UK and Ireland (Dötsch et al.,
2009). Reductions of up to 33% have been achieved across the Kraft processed
cheese product range (Kilcast and den Ridder, 2007). In 2003, Girgis et al. revealed
that the sodium content of white bread could be reduced by up to 25% over six weeks
without affecting the flavour of the product. Ainsworth et al. (1993) found that the
amount of salt added into chilli con carne and ratatouille could be reduced by two-
thirds without affecting overall consumer acceptability of either product. Lucas et al.
(2011) reported that sodium reductions of greater than 50% could be achieved in hash
brown products. Differences in salt reduction rates achievable via this salt reduction
strategy will differ between regions and product type due to differences in initial salt
levels within products, taste threshold and preferences of local consumers and/or the
presence of external salt reduction initiatives (Dötsch et al., 2009). However, a level
of salt reduction will ultimately be achieved for each product below which a loss in
acceptable flavour will become noticeable by consumers (Kilcast and den Ridder,
2007). Therefore, the industry is also focusing on other strategies that will maintain
the perceived salt intensity but at lower salt contents (Dötsch et al., 2009).

1.11.2 Salt Substitutes
Salt substitutes allow replacement of the salty flavour with other, non-sodium
containing ingredients which act by mimicking the effects of sodium (Gillette, 1985).
Currently, there are no known food ingredients which completely mimic the flavour
attributes of sodium chloride. Lithium and ammonium compounds possess a salty

28
taste similar to that of sodium however, lithium compounds are toxic at the levels required to produce a salt substitute effect while ammonium compounds impart an undesirable aroma and are unstable in many processed foods (Doyle, 2008). Calcium and potassium based salt substitutes are also said to have salty taste properties but these compounds are often associated with off-flavours such as metallic or bitter tastes (Kilcast and Den Ridder, 2007; Doyle, 2008). Nonetheless the most common salt substitute used within the food industry today is potassium chloride (KCl). Gillette (1985) found that potassium chloride based salt substitutes enhanced sweetness but also imparted bitter, chemical and metallic off-notes. The bitterness associated with KCl at concentrations required to deliver saltiness is known to limit its industrial use, with 50:50 sodium chloride/potassium chloride blends being a common practical solution (Phelps et al., 2006). Desmond (2006) stated that a significant increase in bitterness and loss of saltiness was observed in sodium chloride/potassium chloride blends over a ratio of 50:50. Gelabert et al., (2003) found that substitution levels of 40% KCl in place of salt in fermented sausages imparted acceptable flavour and textural properties to the food. Sanceda et al., (2003) found partial substitution of salt with KCl up to a ratio of 75:25 acceptable in fish sauce; above this level panellists noted an unacceptable bitter taste. In terms of health, substitution of salt with potassium gives an added health benefit as potassium rich diets have been shown to further decrease blood pressure (Geleijnse et al., 2003). However, in Ireland the FSAI Scientific Committee (2005) are of the opinion that the use of sodium salts incorporating potassium could not be endorsed at this time as concerns were raised about the possible vulnerability of certain population sub-groups to high potassium loads from these substitutes. There are arguments against this view based on the knowledge that the majority of the population consume far less potassium than the recommended daily allowance. The National Academy of the Sciences, Institute of Medicine (IOM) panel members found the case for potassium associated blood pressure reduction so compelling that they raised the recommended daily allowance from 3,500 mg per day to 4,700 mg (AlsoSalt, 2006).

Despite the concerns of the FSAI, considerable research has been undertaken on reducing sodium contents via the partial replacement of salt with KCl. The same perceived saltiness can be achieved using salt mixtures which have lower sodium content, with many of these mixtures being patented and commercialised. Several of
these commercial salt substitutes incorporate a substance which acts to mask the bitterness often associated with the use of KCl. One such salt mixture is AlsoSalt®, a patented salt substitute which has replaced the entire sodium content with a mixture of potassium chloride and the essential amino acid L-lysine mono-hydrochloride. According to the manufacturers, L-lysine has its own salty flavour which also masks the bitterness associated with KCl (AlsoSalt, 2006). Pansalt® is a patented salt replacer where almost half the sodium is removed and replaced by potassium chloride, magnesium sulphate and the essential amino acid L-lysine hydrochloride (Desmond, 2006). According to the manufacturer, the patented usage of the amino acid enhances the saltiness of the salt replacer and masks the taste of potassium and magnesium, while increasing the excretion of sodium from the human body (Desmond, 2006). Other commercial salt mixtures on the market include Lo® salt, Saxa So-low salt and Morton Lite Salt® to name but a few.

Research has also demonstrated that phosphates can be very useful replacements for salt in meat products (Poulanne and Terrell, 1983). Some phosphates used in salt replacement are components of sodium salts; however the usage rate is much lower than that of sodium chloride. Sodium polyphosphate contains 31.24% Na\(^+\) compared to the 39.34% found in sodium chloride and is typically used at a rate of 0.5% compared to 2-4% usage rate for salt (Desmond, 2006). Potassium salts of phosphate are also commercially available and are equally effective as their sodium salt counterparts (Desmond, 2006). Ruusunen et al. (2002) found it possible to produce reduced salt bolognas and cooked hams (1.0-1.4% salt) provided that phosphates were added, with further reductions to the sodium content being possible by replacing sodium phosphate with potassium phosphate.

Other salt substitutes commonly used in food processing include magnesium, calcium, and ammonium chloride, magnesium sulphate, glutamic acid, organic acids, autolyzed yeast products and hydrolyzed vegetable protein products along with certain herbs and spices (Reddy and Marth, 1991; Gillette, 1985). More recently, flake- or dendritic-type salts, which are sodium chloride salts where the crystals are star-like or branched instead of the normal cubic structure, are used as they are purported to impart a sharper salty taste at a lower level (Kilcast and den Ridder, 2007). This use of salt in different particle shapes and sizes may result in a more
controlled delivery of salty taste and flavour to the taste buds in the mouth (Dubois and Tsau, 1992; Morris et al., 2009).

1.11.3 Flavour Enhancers

Flavour enhancers act by supplementing, enhancing or modifying the original taste and/or aroma of a food. These ingredients can create a higher degree of flavour intensity within a food which is not necessarily a salty flavour (Gillette, 1985; Kilcast and den Ridder, 2007). Taste enhancers work by activating receptors in the mouth and throat, which helps compensate for salt reduction (Brandsma, 2006). They are largely based on amino acids and nucleotides and include monosodium glutamate (MSG), glycine salts, guanylic acid salts, inosinic acid salts, certain organic acids, and herbs and spices. There are now a large number of flavour enhancing ingredients commercially available and the number of these products coming onto the market is increasing.

One of the best known flavour enhancers used today is monosodium glutamate or MSG. MSG is the monosodium salt of glutamic acid, one of the most common amino acids found in nature (Anonymous, 2003). As glutamic acid, it is present in virtually all foods including vegetables, seafood, meat, and cheese (Kurihara and Kashiwayanagi, 2000). Glutamic acid is found in all protein containing foods, but only enhances flavours when it appears in its “free” form, that is, not bound together with other amino acids in protein (Anonymous, 2004a). Scientists now believe that glutamates imparts a fifth taste known as ‘umami’ which is described as savoury and meaty and is independent of the four basic tastes of sweet, sour, salty and bitter (Fuke and Ueda, 1996; Ninomiya, 2001). When added to food it is perceived to 'enhance' the natural flavours present (Fuke and Ueda, 1996). Food manufacturers commonly use glutamate to season ready-meals, soups and meat products, ready-made salad dressings, sauces and gravies (Anonymous, 2004a). A small amount of glutamate added into a low sodium product can make it taste as good as its higher salt counterpart as it contains only one-third of the amount of sodium in table salt. Consequently many food manufacturers can reduce the overall salt content in their products by up to 30% (Anonymous, 2004a). However, in recent times people have
begun to report sensitivity to MSG with flushing being perceived as a common side-effect, as is the onset of an asthmatic attack (Collins, 2008).

Yeast autolysates are commonly used in low salt preparations as food manufacturers seek natural alternatives to chemical-based taste enhancers (Brandsma, 2006). Yeast extracts are well known for their clean, bouillon-like taste and in recent times have been used to enhance the impact of ingredients, such as spices (Brandsma, 2006). In particular they are claimed to mask the metallic flavour of KCl (Desmond, 2006). The addition of yeast extracts has been reported to enable salt reductions of 40-60% without compromising palatability, mouthfeel, organoleptic structure or authenticity (DSM, 2007; Brandsma, 2006). The manufacturers of Provesta® flavour ingredients have a number of low sodium yeast autolysates and claim that the co-processed combination of potassium or aluminium chloride and yeast autolysates is significantly less bitter than KCl alone (Desmond, 2006).

Proteins, amino acids and nucleotides are also commonly used as flavour enhancers. Hydrolyzed Vegetable Protein (HVP) sometimes referred to as Hydrolyzed Plant Protein (HPP) is a flavour enhancer used in products ranging from broths to meat products (Anonymous, 2006). There are two kinds of HVP and HPP - light or dark. The light variant is often used in poultry, pork and vegetable products while the dark counterpart is added to products such as sauces, gravies, stews, processed meats and hot dogs (Anonymous, 2006). Some hydrolyzed vegetable (or plant) protein has MSG added to it for an extra non-nutritional sensory boost. The nucleotides disodium inosinate (IMP) and disodium guanylate (GMP) can improve the natural taste and flavour of meat, poultry, fish, vegetables and processed foods (Fuke and Ueda, 1996). These ingredients also help to moderate the basic flavours of sweetness, sourness, saltiness and bitterness. They act to suppress undesirable odours in food such as sulphurous and starchy aromas and the typical aromas associated with hydrolyzed vegetable proteins, as well as the "canned" or "processed" smells of preserves and frozen foods (Anonymous, 2005). Many essential amino acids are used in combination with other flavour enhancers. One such amino acid is lysine which has been shown to have its own unique salty taste without a significant off-taste and also possesses the ability to mask metallic off notes from KCl (AlsoSalt, 2006; Dötsch et al., 2009). Turk (1993) patented a flavour enhancer
which combined lysine with succinic acid; the compound was found to have a salty flavour together with some antimicrobial and antioxidant properties. It is claimed that the product can be used to replace up to 75% of the NaCl from a flavour perspective (Turk, 1993). Arginine is another amino acid which is often claimed to have a salty taste. Its effects on salt or flavour enhancement are varied with one study reporting that it more than doubled the saltiness associated with 4.5g/L NaCl, with other workers reporting effects significantly lower than this (Breslin, 2004; Dötsch et al., 2009). Angus et al. (2005) reported that a combination of arginine and aspartate was more effective than arginine alone.

1.11.4 Other Salt Reduction Strategies

Other strategies coming to the fore at the moment involve technological solutions to reduce the salt content of processed food without altering taste. Recent research evaluated the possibility of enhancing salt perception via the addition of hyperosmotic solutions containing high polymer concentrations of up to 30% in food products such as soups and sauces (Koliandris et al., 2011). This study found a significant enhancement of saltiness in hyperosmotic solutions that contained high polymer concentrations compared to solutions of lower osmolality. These findings suggest that high concentrations of low molecular weight thickeners could be used to enhance saltiness perception in low salt products (Koliandris et al., 2011). Other research indicates that salt perception in a thickened solution is related to the viscosity at low shear rate (Gady et al., 2008). Ferry et al. (2006a) found that starch added in the form of swollen granules substantially improved the perception of salt at high viscosities compared with systems consisting of disrupted granules or polysaccharide solutions. Another recent study investigated the delivery of salt solutions in pulses of different concentrations to determine whether a pulsed delivery profile can affect sensory perception of salt (Morris et al., 2009). Salt solutions were delivered to sensory panellists using a Dynataste system (Hort and Hollowood, 2004) which was developed to allow continuous solution delivery so as to stimulate a real eating experience (Morris et al., 2009). Research has found that pulses of several seconds duration have been reported to not only disrupt taste adaption but also enhance salt perception (Meiselmann and Halpern, 1973). It is proposed that if delivery profiles can affect salt perception then the most advantageous profiles could be used to design
specialized food microstructures which deliver salt taste properties with minimum consumption (Morris et al., 2009). Other research raised the possibility of developing products with different salt levels to optimize the taste perception of consumer groups with different amylase activities. This follows the observation that the level of salt incorporated into starch-thickened foods depended upon the in-mouth amylase activity of the consumer (Ferry et al., 2006b).

1.12 Sensory Evaluation and Its Importance in the Reformulation Process of Food
Sensory analysis is a scientific discipline that applies principles of experimental design and statistical analysis to the interpretation of the human senses for the purpose of evaluating consumer products (ASTM MNL14, 1992). It has been defined as a ‘scientific method used to evoke, measure, analyze and interpret those responses to products as perceived through the senses of sight, smell, taste, touch and hearing’ (Stone and Sidel, 1993; Lawless and Heymann, 1998; Walsh, 2007; Kemp et al., 2009). Scientists today have developed sensory evaluation as a formalized, structured and codified methodology which is used in areas such as quality control, product development, product reformulation and research (Meilgaard et al., 1991; Kemp et al., 2009). The science of sensory evaluation relies on guidelines for the preparation and serving of samples under controlled conditions so that biasing factors are diminished (Walsh, 2007). Test area, product and panel controls are implemented prior to analysis to minimize subject bias and maximize sensitivity (Meilgaard et al., 1991; Kemp et al., 2009). Humans by their nature are a heterogeneous instrument for the generation of data and as a result this data can be highly variable. However, like all other analytical methods, sensory evaluation is concerned with precision, accuracy, sensitivity and the avoidance of false positive results. Therefore, statistical analyses ranging from simple descriptive statistics to much more complex multivariate analyses are routinely applied to the generated data (Walsh, 2007).

Sensory evaluation methods can be classified into two distinct groups - analytical and affective. Analytical methods evaluate differences or similarities as well as quality and/or quantity of the sensory characteristics of a product (Walsh, 2007; Kemp et al., 2009). These methods can be further broken down into
discrimination/difference tests and descriptive tests. Discrimination/difference tests are employed to determine whether sensory panellists can detect differences between products. These tests are often carried out in relation to specific attributes of a food product such as saltiness or sweetness. Panellists then concentrate on a named specific attribute to determine whether a sensory difference exists between products in relation to that particular attribute. Examples of discrimination tests commonly used include simple difference tests, “A” – “Not A” test, difference-from-control test, paired comparison test, 3-alternative forced choice test, triangle test, two-out of-five test and the duo-trio test (Meilgaard et al., 1991; Stone and Sidel, 1993; Lawless and Heymann, 1998; Kemp et al., 2009). Descriptive sensory analysis on the other hand involves the identification and detailed description of both the qualitative and quantitative sensory aspects of a product by a group of highly trained panellists (Meilgaard et al., 1991). The qualitative aspects of a product refer to the perceived sensory attributes of a test sample and include the appearance, aroma, flavour, texture and sound properties which combine to differentiate it from other similar products. The quantitative aspects of a product refer to the intensity at which each of these qualitative aspects or attributes are present in a sample. This type of testing is used in research and development (R&D) and in manufacturing to define sensory properties of a target product for new product development. It can define specifications for a control or standard product for QA/QC and R&D applications, document product attributes before a consumer test to assist in selection of attributes for inclusion in a consumer questionnaire, track sensory changes over time with respect to understanding shelf life, packaging etc., map perceived product attributes for the purpose of relating them to instrumental, chemical or physical properties and measure short term changes in the intensity of specific attributes over time (Meilgaard et al., 1991; Kemp et al., 2009). Panellists are selected for descriptive sensory analysis testing from a large group of candidates on the basis of a physiological test for taste discrimination, taste intensity discrimination, olfactory discrimination and description and their ability to discriminate known textural differences in the specific product for which the panel is to be trained (Meilgaard et al., 1991). A personal interview is conducted with potential panellists to determine interest, availability, and potential for working in a group situation (Meilgaard et al., 1991). Many different descriptive analysis methods have been developed with the more popular tests including the flavour profile method, the texture profile method and the quantitative descriptive
analysis (QDA®) method. Other descriptive methods available include spectrum descriptive analysis, free-choice profiling and time-intensity descriptive analysis. The principal purpose of affective or consumer tests on the other hand are to assess the preference for, and acceptability of, new product ideas or specific product attributes by potential consumers of the product (Meilgaard et al., 1991; Walsh, 2007). Affective tests are used mainly by manufacturers of consumer goods and have been proven to be highly effective as a principal tool in designing products and services that will sell in larger quantity and/or attract a higher price (Meilgaard et al., 1991; Walsh, 2007). Reasons for conducting affective tests include; product maintenance, product improvement or optimization, development of new products, assessment of market potential, product category review and support for advertising campaigns (Meilgaard et al., 1991; Kemp et al., 2009). A large number of sensory responses are normally required for affective tests and potential panellists are usually selected from those who meet certain criteria such as age, current consumption of products or other criteria specified by the test organisers (Charley and Weaver, 1998; Lawless and Heymann, 1998). Affective tests can be broken down into qualitative or quantitative methods. Qualitative affective tests measure subjective responses of a sample of consumers to the sensory properties of products by having consumers talk in an interview or small group setting and include focus groups, focus panels and one-on-one interviews. Quantitative affective tests determine the responses of a large group of consumers to a set of questions regarding preference and liking of sensory aspects of a product and include preference tests and acceptance tests.

It is currently estimated that approximately 75% of all new products introduced onto the commercial market fail in their first year as manufacturers overlook the importance of the consumer voice in the product development or reformulation process (Buisson, 1995; Kemp et al., 2009). The incorporation of sensory evaluation data, such as consumer testing, during the product development or reformulation process allows for a more cost effective delivery of acceptable new or improved products to consumers without a risk of potential product failure (Lawless and Heymann, 1998; Kemp et al., 2009). The sensory attributes of a food remain one of the most important factors that influence consumers to purchase one food product in preference to another (Farley and Reed, 2005). Saltiness as a sensory attribute is important to the overall acceptability of many food products while salt itself plays a
vital role in the development of characteristic flavours and textures associated with several foods (Kilcast and den Ridder, 2007). Therefore, sensory challenges arising from salt reduction relate not only to maintaining acceptable salt perception but also to its effect on the additional sensory properties of food products. However, the impact of issues such as dish complexity, food texture and flavour on consumers’ acceptability of reduced salt foods are rarely taken into account by governing health bodies when recommendations to reduce salt in the populations’ diet are made (Walsh, 2007). The fact that many consumers perceive reduced salt foods and sodium restricted diets to be bland, tasteless and generally unpalatable and unpleasant (Walsh 2007) highlights the importance of maintaining the flavour and taste of the original salted product when formulating reduced salt foods (Bertino et al., 1981). Sensory analysis can act as a highly effective tool to be employed when striving to maintain sensory properties of food following salt reductions. In the early stages of product development sensory and consumer testing can be used to recognize the importance of sensory attributes driving acceptability across a particular product range (Kemp et al., 2009). Its importance in determining the impact of up-scaling test kitchen samples to a larger process plant scale production is vital in the developmental stages of a product. Sensory analysis is also highly important in determining the effect of raw material changes or modifications to the production process as regards sensory quality and acceptability. Additionally, integration of data from sensory and instrumental analysis can supply insights into the chemical and physical properties driving specific sensory attributes. Where significant correlations exist between instrumental and sensory data, it may be possible to dispense with the use of a sensory panel in favour of an instrumental test, a scenario often seen during quality testing (Kemp et al., 2009). The utilization of a series of sensory difference tests can help manufacturers and industry personnel determine exactly how much salt can be removed from food products before consumers begin to notice a sensory difference. This strategy is well suited when adopting a gradual salt reduction approach. Difference tests can also be applied when incorporating new salt substitutes or flavour enhancers into reduced salt foods. This provides a method of determining whether the new ingredients can compensate for the loss of salt, while application of descriptive sensory analysis techniques to reduced salt food can provide essential information as to the precise effect lowering salt has on the sensory properties of a food. Coupling sensory methods with a series of preference and acceptability tests can provide manufacturers
with a highly effective strategy for reducing salt in their products without significant loss of consumers due to changed sensory properties.

1.13 Thesis Objectives

Currently there is very little published information on the impact of salt reductions and the addition of new ingredients on the sensory acceptability of commercial ready-meals. Therefore, the primary aim of this thesis was to determine the effect of salt reduction and the addition of salt substitutes and flavour enhancers on the sensory properties and acceptability of several commercial ready-meals available on the Irish market. By conducting this research it is hoped to make recommendations to the ready-meal industry in Ireland which will allow them to develop reduced salt products and meet FSAI salt reduction targets. The present literature review has highlighted a number of knowledge gaps which are addressed in six specific research objectives outlined below.

1. The first objective (chapter two) was to determine salt levels in ready-meals available on the Irish market and to understand how these products contributed to the adult recommended dietary allowance of salt in Ireland. This was achieved by conducting a product survey of 68 ready-meals readily available on the Irish market. An investigation was also carried out to establish whether global calls for salt reduction in processed convenience foods was impacting on the levels of salt in ready-meals in Ireland. This was carried out by re-surveying 51 of the ready-meals four years after the original survey.

2. The second objective (chapter three) was to gain an understanding of Irish consumer attitudes towards ready-meals and current salt-associated issues in Ireland. This was achieved by distributing a questionnaire to 357 consumers in both rural and urban/city areas of Ireland.

3. The third objective (chapter four) was to determine the effect of a number of popular salt reduction strategies on the sensory acceptability of three frozen ready-meals. Initially a suite of sensory analyses were used to determine the effect of gradually reducing salt levels on the sensory acceptability of the
ready-meals. A range of commercially available salt substitutes and flavour enhancers were subsequently sourced and added to these products and their effect on the sensory properties investigated.

4. The fourth objective (chapter 5) was to investigate the impact of salt reductions on the sensory characteristics and volatile composition of three chilled ready-meals using flavour profile sensory analysis coupled with solid-phase microextraction (SPME) and gas chromatography mass spectrometry (GC-MS) instrumental analysis.

5. The fifth objective (chapter 6) was to examine the use of herbs, spices and whey proteins added as potential natural salt substitutes on the sensory acceptability of three reduced salt chilled ready-meals.

6. The sixth objective (chapter 7) was to establish whether consumer salt taste thresholds affected the sensory acceptability of several reformulated reduced salt vegetable soups. This involved assessing detection and recognition thresholds for salt and determining if thresholds had an effect on sensory acceptability scores, perceived saltiness and purchase intent.
Chapter 2

2.1 Abstract

The levels of salt in ready-meals available on the Irish market were surveyed to determine the potential contribution these products make to an Irish adults RDA of salt. The study found that of 68 ready-meals surveyed 52 (78%) contained greater than or equal to 50% of the RDA of salt for Irish adults, currently a maximum of 4g per day. Eight of the ready-meals contained greater than or equal to the RDA of salt in a single serving, of which two contained more than twice the RDA, while one product contained greater than three times the RDA. Only 15 ready-meals contained less than 50% of the RDA of salt; however, the accuracy of declared salt and sodium levels was questioned when the products were analysed using an atomic absorption spectrophotometer. In total, 29% of the surveyed samples (n=20) had declared sodium levels which significantly differed (p<0.05) from sodium levels determined by analysis. A follow up survey, four years after the original, revealed that of 51 ready-meals re-examined 12 had no change in overall declared salt content, 30 declared a decrease in salt levels on pack with an average reduction of 0.71g of salt, 9 of which were significantly lower (p<0.05). The remaining 9 ready-meals all showed an increase in declared salt content, one of which appeared significantly higher (p<0.05). Overall, this study found that the level of salt in ready-meals in Ireland is very high and despite an overall mean reduction of 0.4g of salt between 2006 and 2010, on average these meals still contained 65% of an Irish adult RDA for salt. The study also highlighted the need for changes to salt labelling legislation to ensure clear declaration of both salt and sodium contents across all food products. The input of the consumer in the development of legislation regarding salt labelling is of vital importance, as any salt labelling system implemented needs to be concise, clear and easily understood in order for it to be effective.
2.2 Introduction

Processed foods, including soups, ready-meals and comminuted meat products, are a leading contributor to salt intake worldwide (Durack et al., 2008) and account for approximately 75% of daily salt intakes (Dyer et al., 1997; Grimes et al., 2008). However, over consumption and over reliance on salt within the food industry has led many health agencies and authorities throughout the world to question its health effects. A technical report produced in 2003 by the World Health Organization (WHO) recommends the consumption of less than 5g of salt (or <2g sodium) per day as a population nutrient intake goal (World Health Organization, 2003). Since these recommendations back in 2003 the United Kingdom (UK) has set the benchmark worldwide in terms of salt reduction strategies and to date salt reductions between 20-30% have been achieved in a broad spectrum of processed foods (He and MacGregor, 2008). In Ireland, the Food Safety Authority of Ireland (FSAI) has endorsed these recommendations, with the aim of reducing the average population intake of salt down to 6g per day as an achievable target. Presently in Ireland there is limited published data available on the salt content of processed foods. In March 2011 SafeFood published the results of a survey of salt levels in soup in catering establishments on the island of Ireland. The report found that the average portion of soup (approximately 303g) contained 60% of the RDA of salt intake for an Irish adult and that one in ten of the samples contained more salt than the RDA of salt in a single serving (SafeFood, 2011). Worryingly no such survey exists for meat based ready-meals such as lasagnes and curries in Ireland. In the UK a study carried out in 2003 by the Food Standards Agency (FSA) highlighted the requirement for a reduction of salt added to ready-meal formulations. The study which surveyed a total of 69 ready-meals found that 83% of all standard ready-meals contained more than 40% of a days’ maximum recommended salt intake and found that one meal actually contained 5.9g of salt per portion corresponding to ~99% of the target daily intake for an adult (based on the UK RDA of 6g salt per day) (FSA, 2003). A more recent study conducted by Consensus Action on Salt and Health (CASH) in the UK highlighted particularly high levels of salt in many popular takeaways and ready-meals. One example from the study revealed a takeaway curry bought with all the extras could contain as much as 20.5g salt, while data published on levels of salt in ready-meals revealed that many popular meals were found to contain more than or at least 50% of the UK’s daily salt maximum of 6g a day (Consensus Action on Salt and Health, 2010). Given the high
levels of salt reported in these products in combination with the fact that the RDA of salt in Ireland is equivalent to 4g per day as opposed to 6g per day, the contribution of these products to Irish adults mean daily salt intakes could be highly significant.

Due to the current popularity of the ready-meal format in Ireland (Mitchell et al., 2011) and the increasing pressure being put on the food industry to reformulate their products with reduced salt levels, a survey was conducted to determine the salt content of several popular ready-meals available on the Irish market. The survey had several aims including; 1) the determination of the accuracy of the sodium and/or salt content information provided to consumers on nutritional labels; 2) to establish the contribution these ready-meals made to the RDA of salt in Ireland, and 3) to investigate the achievements made by the food industry in the area of salt reduction in ready-meals four years after the original survey.

2.3 Materials and Methods

2.3.1 Ready-Meal Sampling
In 2006 sixty eight ready-meal samples representing fourteen different brands available on the Irish market, both frozen and chilled, were purchased from three major retail stores including Marks and Spencer, Tesco and Dunnes Stores, and from three smaller convenience stores namely Spar, Centra and SuperValu, in Dublin City Centre between March and June 2006. Individual or single-serve samples weighing approximately 300-400g were purchased. In 2010 fifty one of the original sixty eight ready-meals were re-purchased from the same major retail and convenience stores in Dublin City Centre between October and December 2010. The product name, weight and sodium and/or salt content as declared on the nutrition labels were recorded.

2.3.2 Determination of the Sodium Content by Atomic Absorption Spectrometry
All 2006 ready-meals were analysed using the atomic absorption spectrometer to determine if the sodium levels stated on the packs were real and accurate. The entire contents of each ready-meal were scraped into a Moulinex Iseo 1.4L 450watt food processor (Moulinex, France) and mixed at low speed for 2 minutes. Three samples
(0.5g) from each ready-meal were removed from the food processor and placed into acid washed, oven dried 100ml conical flasks. 10mls of 10% nitric acid and 5mls of 70% perchloric acid was added to each conical flask, placed on a hotplate, initially on a low heat, until the sample dissolved and left simmering until the contents of the flask went clear (approx. 10mls). Flasks were allowed to cool and then made up to 100mls using distilled water and 1ml of 3M KCl. 1ml of this sample digest was transferred into a 100ml volumetric flask with 1ml 3M KCl and diluted to volume (100ml) with distilled water. Standards used for instrument calibration were prepared by diluting 0.1ml and 0.02ml of 1000mg/L Na\(^+\) calibrated stock solution (JVA Analytical Ltd., Dublin 12, Ireland) with 2ml of 3M KCl in 200ml distilled water giving 0.5mg/L and 0.1mg/L Na\(^+\) standards respectively. Sample concentrations were read using Perkin Elmer Atomic Absorbance Spectrometer 3110 (Perkin-Elmer, Norwalk, CT, USA) using a hollow cathode ray lamp at an emission wavelength of 590 nm. Sodium and salt levels were calculated as mg/100g using equation (1) and (2) below:

\[
[Na, mg/100g] = \frac{[AA, ppm] \times 100 \times 10}{Sample\ weight\ (g)\times 10} \tag{1}
\]

\[
[\text{Salt, g/100g}] = \frac{[Na, mg/100g] \times 2.5}{1000} \tag{2}
\]

### 2.3.3 Data Analysis

Food label data collected from all ready-meals were entered into Microsoft Excel 2003 spreadsheets. All reported atomic absorption information is the mean of three replicated samples. This information was compared with declared nutritional information as reported on individual product packs and subjected to one-sample t-tests using Microsoft Excel 2003 to determine if any significant discrepancies were apparent between declared and measured sodium values. Similarly declared salt data from 2006 and 2010 were subjected to one-sample t-tests to determine if any significant decreases or increases were observed for individual ready-meals.
2.4 Results and Discussion

2.4.1 Nutritional Label Information

2.4.1.1 Sodium Analysis of 2006 Ready-Meals
Compliance with declared sodium contents on nutritional labels was investigated via the measurement of sodium on an atomic absorbance spectrometer (A.A.), results of which are presented in Table 1. The 0.5mg/L and 0.1mg/L Na\(^+\) standards prepared for instrument calibration were analyzed intermittently throughout ready-meal sampling to ensure instrument precision was maintained during analyses. From Table 1 it can be seen that A.A. measurements for 3 of the 68 ready-meals analysed corresponded exactly with declared sodium levels on packs. These meals were St. Bernard’s chicken curry and rice, Weight Watchers chicken tikka and rice and Unislim beef lasagne. Of the remaining ready-meals 29% (n=20) were found to have significantly different (p<0.05) declared sodium levels in comparison to those which were measured. Approximately 53% (n=36) of the ready-meals surveyed had sodium measurements which were lower than those declared on pack with an average difference of approximately 0.07g per 100g between declared and measured sodium levels. Of these 36 ready-meals, 6 had a difference of greater than 0.10g per 100g (p<0.05) between declared and measured sodium levels, with the average measurement among these 6 meals being approximately 0.16g lower than those declared on pack. Food manufacturers are often wary of proclaiming their intention to reduce salt over fears consumers may turn to other rival products with preconceived ideas that reduced salt will mean reduced taste. Therefore, the observed differences in salt content could be a result of food manufacturers adopting a ‘reduction by stealth’ strategy. An additional 41% (n=28) of the ready-meals surveyed were found to have sodium levels which were higher than those declared on pack, with an average increase of approximately 0.11g per 100g.
Table 2.1: Declared Sodium Content as Reported on Nutritional Label and Actual Sodium Contents as Measured by Atomic Absorption Spectrophotometer

<table>
<thead>
<tr>
<th>Ready-Meal</th>
<th>Na(^{7}/100\text{g} , Label\text{\textsuperscript{1}}</th>
<th>A.A.\text{\textsuperscript{2}}</th>
<th>Ready-Meal</th>
<th>Na(^{7}/100\text{g} , Label\text{\textsuperscript{1}}</th>
<th>A.A.\text{\textsuperscript{2}}</th>
</tr>
</thead>
<tbody>
<tr>
<td>M&amp;S lasagne</td>
<td>0.25</td>
<td>0.21±0.01</td>
<td>St Bernards chicken curry*</td>
<td>0.21</td>
<td>0.21±0.01</td>
</tr>
<tr>
<td>M&amp;S chicken tagliatelle</td>
<td>0.19</td>
<td>0.09±0.02</td>
<td>Weight Watchers chicken curry*</td>
<td>0.22</td>
<td>0.23±0.01</td>
</tr>
<tr>
<td>M&amp;S pineapple chicken curry*</td>
<td>0.20</td>
<td>0.21±0.02</td>
<td>Weight Watchers chicken hotpot</td>
<td>0.25</td>
<td>0.41±0.01</td>
</tr>
<tr>
<td>M&amp;S shepherds pie</td>
<td>0.40</td>
<td>0.59±0.01</td>
<td>Weight Watchers chicken tikka*</td>
<td>0.13</td>
<td>0.13±0.01</td>
</tr>
<tr>
<td>M&amp;S sweet &amp; sour chicken</td>
<td>0.37</td>
<td>0.31±0.01</td>
<td>Weight Watchers sausages in cider gravy &amp; vegetable mash</td>
<td>0.22</td>
<td>0.17±0.02</td>
</tr>
<tr>
<td>M&amp;S vegetarian chilli</td>
<td>0.28</td>
<td>0.18±0.01</td>
<td>Weight Watchers thai green curry</td>
<td>0.21</td>
<td>0.17±0.03</td>
</tr>
<tr>
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<td>0.22</td>
<td>0.17±0.02</td>
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<td>0.29±0.02</td>
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<tr>
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<td>0.16</td>
<td>0.17±0.01</td>
<td>Weight Watchers beef lasagne</td>
<td>0.30</td>
<td>0.22±0.03</td>
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<td>M&amp;S vegetarian curry</td>
<td>0.30</td>
<td>0.20±0.03</td>
<td>Weight Watchers vegetarian chilli*</td>
<td>0.14</td>
<td>0.28±0.01</td>
</tr>
<tr>
<td>M&amp;S chicken arrabbiata</td>
<td>0.24</td>
<td>0.18±0.01</td>
<td>Weight Watchers Mexican chilli &amp; deep fried potato wedges</td>
<td>0.30</td>
<td>0.29±0.01</td>
</tr>
<tr>
<td>Tesco beef lasagne</td>
<td>0.20</td>
<td>0.26±0.03</td>
<td>Unislim beef lasagne</td>
<td>0.15</td>
<td>0.15±0.01</td>
</tr>
<tr>
<td>Tesco chicken &amp; black bean</td>
<td>0.30</td>
<td>0.42±0.02</td>
<td>Unislim sweet &amp; sour chicken</td>
<td>0.23</td>
<td>0.30±0.02</td>
</tr>
<tr>
<td>Tesco chicken madras</td>
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<td>0.20±0.03</td>
<td>Unislim chicken &amp; vegetable casserole</td>
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</tr>
<tr>
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<td>0.20</td>
<td>0.19±0.02</td>
<td>Carroll Cuisine chicken curry</td>
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<td>1.20±0.04</td>
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<tr>
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<td>1.22±0.01</td>
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<tr>
<td>Tesco value chicken curry</td>
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<td>0.23±0.03</td>
<td>Carroll Cuisine chicken tikka masala</td>
<td>0.7</td>
<td>0.80±0.01</td>
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<tr>
<td>Tesco Value Cottage Pie</td>
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<td>0.09±0.02</td>
<td>Carroll Cuisine chicken &amp; pasta bake</td>
<td>0.7</td>
<td>0.79±0.02</td>
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<tr>
<td>Tesco value spaghetti bolognese</td>
<td>0.10</td>
<td>0.07±0.01</td>
<td>Carroll Cuisine lasagne</td>
<td>N/G</td>
<td>0.30±0.02</td>
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<td>Tesco lasagne</td>
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<td>0.22±0.01</td>
<td>Kohinoor pilau rice</td>
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<td>0.22±0.01</td>
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<td>Kohinoor balti chicken curry</td>
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<td>0.53±0.01</td>
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<td>0.26±0.01</td>
<td>Kohinoor chicken korma</td>
<td>0.18</td>
<td>0.14±0.01</td>
</tr>
<tr>
<td>Tesco oriental sweet &amp; sour chicken*</td>
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<td>0.31±0.02</td>
<td>Kohinoor chicken jalfrezi</td>
<td>0.38</td>
<td>0.20±0.01</td>
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<td>Tesco chicken tikka biryani</td>
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<td>0.12±0.01</td>
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<td>0.59±0.02</td>
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<tr>
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<td>0.34±0.01</td>
<td>Findus chicken curry</td>
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<td>0.24±0.03</td>
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<tr>
<td>Birdseye lasagne</td>
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<td>0.42±0.01</td>
<td>Findus beef curry</td>
<td>0.20</td>
<td>0.22±0.02</td>
</tr>
<tr>
<td>Birdseye chicken supreme*</td>
<td>0.10</td>
<td>0.28±0.01</td>
<td>SuperValu chicken &amp; bacon bake</td>
<td>0.30</td>
<td>0.18±0.02</td>
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<tr>
<td>Birdseye spaghetti bolognese</td>
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<td>0.27±0.02</td>
<td>SuperValu beef lasagne</td>
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<td>0.33±0.02</td>
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<td>SuperValu Irish stew</td>
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<td>0.45±0.04</td>
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<td>0.29±0.03</td>
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<td>0.17±0.01</td>
</tr>
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<td>0.18±0.01</td>
<td>Quorn cottage pie</td>
<td>0.40</td>
<td>0.35±0.01</td>
</tr>
<tr>
<td>St. Bernards chilli con carne</td>
<td>0.20</td>
<td>0.16±0.01</td>
<td>Shaw's deli lasagne</td>
<td>0.34</td>
<td>0.28±0.01</td>
</tr>
</tbody>
</table>

\textsuperscript{1} Level of sodium printed on ready-meal nutritional label. * Mean level of sodium determined by A.A. triplicate analysis. * Ready-meal contained rice. N/G: information not given on pack. Numbers in **bold italics** are significantly different (p<0.05), calculated using one-sample t-tests.
Twenty of these ready-meals were found to have significant differences (p<0.05) between declared and measured sodium levels. Ten of the 28 ready-meal samples analyzed exceeded the label claim for sodium by more than 50%, of which 5 ready-meals exceeded the declared sodium content by more than 100%.

Of the different brands surveyed Birdseye ready-meals were found to show the biggest differences between declared and measured sodium levels. All sodium levels declared on pack were lower than measured values with differences ranging from 0.17g/100g up to 0.24g per 100g between both sets of figures. One exception was their ‘Healthy Option’ chicken curry and rice whose measured values were only 0.03g per 100g higher than declared values. In contrast, 3 of the 4 Dunnes Stores own brand ready-meals surveyed were found to have declared sodium levels which were in fact higher than actual measured sodium concentrations. Measured sodium levels were found to be between 0.09g and 0.16g lower (per 100g) than their on pack declared values. No other trends were observed with ready-meals from each of the remaining brands showing both increases and decreases in measured sodium levels.

The variation in the accuracy of sodium levels is worrying from a consumer viewpoint. When a consumer reads the nutritional information on a product it is presumed that the information is both accurate and correct. However, results from this part of the study have shown that only 3 of the 68 ready-meals analyzed had sodium contents as declared on pack. Sixty five of the meals were found to have sodium levels either above or below the declared levels. While it is highly encouraging that over 50% of the meals had lower salt contents than those declared, there is no way for the consumer to know this unless it is accurately and clearly stated on pack. It is also of great concern that over 40% of the meals surveyed had higher sodium levels than those claimed on pack. The fact that 10 meals exceeded these claims by more than 50% is extremely worrying and highlights the need for a more regulated approach for monitoring the declared levels of nutrients on nutritional information labels.

It should be noted that the differences observed between the declared and measured sodium levels may potentially arise from the different methods of sodium analysis used by the manufacturers and those used in the present study.
2.4.1.2 Nutritional Labelling Claims – 2006

Of the 68 ready-meals surveyed, one did not include any information regarding the level of sodium or salt in the meal on the nutritional label. The remaining 67 ready-meals all contained sodium levels both per 100g and per serving. Only 40 ready-meals included information regarding the level of salt in the meals. Those that did state the salt contents typically included it as small writing under the nutritional information box, with the exceptions of Tesco and Marks and Spencers own-branded products, both of whom clearly stated salt equivalents in nutritional label.

Within the EU, the placing of nutrition values on a product is optional according to the Council Directive 90/496/EEC of 24 September 1990 on nutrition labelling for foodstuffs (Przyrembel, 2004). However, as stated in Article 4 of Directive 90/496/EEC “where nutritional labelling is provided, the information to be given shall consist of either group 1 or group 2 in the following order: Group 1 (a) energy value; (b) the amount of protein, carbohydrate and fat. Group 2 (a) energy value (b) the amounts of protein, carbohydrates, sugars, fats, saturates, fibre and sodium. Where a nutritional claim is made for sugars, fats, saturates, fibre and sodium, the information to be given shall consist of group 2.” In the present study none of the ready-meals surveyed made a claim relating to sodium or salt and therefore, under EU regulations these companies were under no obligation to state the levels of either the sodium or salt content on the nutrition label. Hence, the one ready-meal surveyed that did not include sodium or salt contents on the nutritional label was under no obligation to do so and in actual fact met the requirement set out in “Group 1” of the above stated directive. The fact that 67 ready-meals included sodium contents is a positive sign and implies that food manufacturers are aware of the issue relating to salt and health. In Ireland the Food Safety Authority of Ireland (FSAI) encourages the food industry, on a voluntary basis to label 'salt equivalents' in the same field of view as the nutrition panel. In 2006, approximately 59% (n=40) of the ready-meals surveyed included ‘salt equivalents”, however, only Tesco and Marks and Spencer’s included it in the same field of view on the nutrition panel.
2.4.1.3 Nutritional Labelling Claims – 2010

Of the 51 ready-meals which were re-surveyed in 2010, 50 contained information relating to both sodium and salt contents. The one ready-meal that did not contain any information regarding sodium and salt levels was the same meal which did not contain this information in 2006. In comparison with 2006 findings, salt content information or ‘salt equivalents’ appeared on the nutritional information label under sodium content for all ready-meals, as opposed to small writing underneath the nutrition label as found in 2006. Thirty four of the 51 re-surveyed ready-meals contained both sodium and salt values per 100g and per serving. Five were found to include sodium and salt levels per serving only while 8 included similar information per 100g only. A further 3 meals included sodium and salt per 100g and its salt equivalent per serving. This increased presence of salt content information on the nutritional labels is a marked improvement from 2006 and shows food manufactures commitment to and awareness of the salt issue. 2010 also saw the appearance of guideline daily amounts (GDA) information panels on the front of several ready-meals which previously had not been present in 2006. This panel clearly stated the amount of salt, in addition to calories, sugars, fat and saturates in grams (g), per serving and indicated the percent contribution each of these nutrients made to an adults GDA. However, it must be stated that information relating to the GDA of salt is calculated based on the UK population intake target of 6g/day and not on the Irish RDA of 4g/day. In spite of this, these new additions to food labels make the reading and interpretation of nutritional information more consumer-friendly. Something which is very beneficial given the fact that Grimes et al., (2009) reported that 65% of 474 participants surveyed were unable to correctly identify the relationship between salt and sodium and found that 40% considered salt and sodium to be the same substance. Consumers who are simply not aware of the connection between sodium and salt may in fact read the sodium content on the food label but due to lack of information would not connect it with salt content and/or may indeed think it is the salt content (Mitchell et al., 2011). Therefore, the increased presence of front of pack labelling on ready-meals in 2010 will help consumers make more informed food choices and avoid any confusion they have between sodium and salt.
2.4.2 Contribution of Ready-Meals Surveyed in 2006 to an Irish Adults Salt Intake and RDA

2.4.2.1 Salt Content of Ready-Meals – 2006

The average weight of all ready-meals surveyed in 2006 was approximately 375g and ranged from 190g to 500g per serving. Figure 1 clearly illustrates that the vast majority of the meals surveyed contained greater than or equal to 50% of the RDA of salt per serving. In fact of the 67 ready-meals surveyed 52 (78%) contained greater than or equal to the 50% of the RDA of salt for Irish adults, currently a maximum of 4g of salt per day (FSAI Scientific Committee, 2005). Eight of the ready-meals surveyed were found to contain greater than or equal to 4g in one serving. Alarmingly two of these eight meals contained greater than 200% of the RDA of salt with one of these two meals containing over 300% of the RDA of salt i.e. over three days worth of salt in one meal. Only 22% (n=15) of the ready-meals surveyed had less than 50% of the RDA of salt, the lowest of which was found in Birdseye spaghetti bolognese at 1.0g of salt in one serving. However, based on previous results (Table 1) this meal was found to contain 0.27g of salt per 100g when analyzed on the A.A., which equates to 2.7g of salt per 400g ready-meal or 68% of the RDA, and therefore, the accuracy of this declared low level of salt is suspicious.

![Figure 2.1: Salt Content of Each Individual Ready-Meal Surveyed in 2006 (n=68)](image)

Green Line = Population intake target of 6g per day. Pink line = RDA salt in Ireland of 4g per day. Red Line = 50% of the RDA of salt in Ireland.
2.4.3 Salt Reduction Progress - Comparison of the Salt Content of Ready-Meals in 2006 and 2010

Table 2 presents data on the salt content of a sample of 51 ready-meals originally surveyed in 2006 which were re-surveyed in 2010. Data shows that of the 51 ready-meals surveyed in both years 23% (n=12) showed no change in overall declared salt content. However, the vast majority of the ready-meals (59%; n=30) showed a decrease in salt levels declared on pack with and an average reduction of 0.71g of salt. These reductions varied from 0.1g per meal up to a high of 2.8g per meal in SuperValu beef lasagne. Of the 30 ready-meals that lowered their salt content 9 were found to be significantly lower (p<0.05) in 2010 compared with 2006 values. These meals included 4 Tesco branded ready-meals, 2 SuperValu branded ready-meals, 1 Weight Watchers branded ready-meal, 1 Quorn branded ready-meal and 1 Kohinoor branded ready-meal. These 9 meals reduced their overall salt content by between 1.0g and 2.8g per meal. Eighteen percent of the ready-meals surveyed (n=9) saw an increase in the level of salt declared on pack between 2010 and 2006. The level of salt in these meals increased by an average of 0.49g per meal over the four year period, with one meal, namely Tesco oriental sweet and sour chicken with rice, more than doubling the level of salt present in the meal from 1.7g per meal in 2006 up to 3.7g in 2010 (p<0.005).

Overall the average salt content of all 51 ready-meals was reduced by 0.4g from an average of 3.0g of salt per serving in 2006 down to 2.6g of salt per serving in 2010. This equates to an overall average reduction of 10% in terms of the ready-meals contribution to RDA of salt. However, despite the overall positive reduction observed between 2006 and 2010, the average salt content of all 2010 ready-meals still contained approximately 65% of an Irish adults RDA of salt. This coupled with the fact that 18% of all ready-meals surveyed in 2010 had increased the level of salt present in their products since 2006 highlight the need to significantly reduce the level of salt in ready-meals across the board.
### Table 2.2: Declared Concentration of Salt in Ready-Meals Surveyed in 2006 and 2010

<table>
<thead>
<tr>
<th>Ready-Meal</th>
<th>Salt/Serving&lt;sup&gt;†&lt;/sup&gt;</th>
<th>Ready-Meal</th>
<th>Salt/Serving&lt;sup&gt;†&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>M&amp;S lasagne</td>
<td>2.4</td>
<td>2.4</td>
<td>Dunnes Stores beef lasagne</td>
</tr>
<tr>
<td>M&amp;S chicken tagliatelle</td>
<td>2.0</td>
<td>1.9</td>
<td>St. Bernards chilli con carne</td>
</tr>
<tr>
<td>M&amp;S shepherds pie</td>
<td>1.9</td>
<td>1.7</td>
<td>St. Bernards chicken curry*</td>
</tr>
<tr>
<td>M&amp;S sweet &amp; sour chicken</td>
<td>1.5</td>
<td>1.1</td>
<td>Weight Watchers chicken curry*</td>
</tr>
<tr>
<td>M&amp;S chicken tikka masala</td>
<td>2.4</td>
<td>3.0</td>
<td>Weight Watchers chicken hotpot</td>
</tr>
<tr>
<td>M&amp;S chicken arrabbiata</td>
<td>2.4</td>
<td>2.3</td>
<td>Weight Watchers chicken tikka*</td>
</tr>
<tr>
<td>Tesco beef lasagne</td>
<td>2.0</td>
<td>2.2</td>
<td>Weight Watchers sausages in cider gravy &amp; vegetable mash</td>
</tr>
<tr>
<td>Tesco chicken &amp; black bean</td>
<td>3.1</td>
<td>2.8</td>
<td>Weight Watchers Thai green chicken curry</td>
</tr>
<tr>
<td>Tesco chicken madras</td>
<td>2.6</td>
<td>1.8</td>
<td>Weight Watchers spaghetti bolognese</td>
</tr>
<tr>
<td>Tesco value lasagne</td>
<td>3.7</td>
<td>1.1</td>
<td>Weight Watchers beef lasagne</td>
</tr>
<tr>
<td>Tesco value chicken curry</td>
<td>2.1</td>
<td>0.9</td>
<td>Weight Watchers Mexican chilli &amp; deep fried potato wedges</td>
</tr>
<tr>
<td>Tesco value cottage pie</td>
<td>1.5</td>
<td>1.9</td>
<td>Carroll Cuisine chicken curry</td>
</tr>
<tr>
<td>Tesco value spaghetti bolognese</td>
<td>1.3</td>
<td>1.2</td>
<td>Carroll Cuisine sweet &amp; sour chicken</td>
</tr>
<tr>
<td>Tesco lasagne</td>
<td>3.4</td>
<td>2.4</td>
<td>Carroll Cuisine chicken tikka masala</td>
</tr>
<tr>
<td>Tesco vegetable lasagne</td>
<td>2.1</td>
<td>2.0</td>
<td>Carroll Cuisine chicken &amp; pasta bake</td>
</tr>
<tr>
<td>Tesco Italian chicken lasagne</td>
<td>2.6</td>
<td>2.3</td>
<td>Carroll Cuisine lasagne</td>
</tr>
<tr>
<td>Tesco oriental sweet &amp; sour chicken*</td>
<td>1.7</td>
<td>3.7</td>
<td>Kohinoor pilau rice</td>
</tr>
<tr>
<td>Tesco Indian chicken tikka biryani</td>
<td>2.8</td>
<td>0.8</td>
<td>Kohinoor Balti chicken curry</td>
</tr>
<tr>
<td>Birdseye chicken curry*</td>
<td>1.5</td>
<td>2.0</td>
<td>Kohinoor chicken korma</td>
</tr>
<tr>
<td>Birdseye lasagne</td>
<td>1.5</td>
<td>1.6</td>
<td>Kohinoor chicken jalfrezi</td>
</tr>
<tr>
<td>Birdseye chicken supreme*</td>
<td>1.3</td>
<td>1.2</td>
<td>SuperValu beef lasagne</td>
</tr>
<tr>
<td>Birdseye spaghetti bolognese</td>
<td>1.0</td>
<td>0.6</td>
<td>SuperValu cottage pie</td>
</tr>
<tr>
<td>Birdseye Healthy chicken curry*</td>
<td>1.8</td>
<td>1.0</td>
<td>SuperValu chicken curry*</td>
</tr>
<tr>
<td>Dunnes Stores cottage pie</td>
<td>3.2</td>
<td>2.6</td>
<td>Denny cottage pie</td>
</tr>
<tr>
<td>Dunnes Stores vegetable lasagne</td>
<td>3.3</td>
<td>3.2</td>
<td>Quorn cottage pie</td>
</tr>
<tr>
<td>Dunnes Stores Chinese chicken curry*</td>
<td>4.5</td>
<td>3.8</td>
<td></td>
</tr>
</tbody>
</table>

<sup>†</sup> grams (g) of salt in each individual portion. * Ready-meal contained rice. N/G: information not given on pack.
Numbers in <em>bold italics</em> are significantly different (p<0.05), calculated using one-sample t-tests.
2.5 Conclusions
Results from the present study highlighted the importance of a salt reduction programme for ready-meals on the island of Ireland. Despite the positive improvements observed with regards the content of salt in ready-meals between 2006 and 2010, the concentration of salt in these products remained very high with an average total salt content of 2.6g per serving in 2010 equating to 65% of an Irish adults RDA of salt. Significant improvements were seen in the reporting of sodium and salt concentrations between 2006 and 2010 however, there is a need to introduce mandatory salt labelling legislation which would guarantee that the reporting of both sodium and salt would be identical across all food items. Of the upmost importance is that this labelling system is clear and ease to understand from a consumer view-point. The present study also highlighted the inaccuracy of declared sodium on packs and emphasized the need for a tighter regulation of nutrients declared on nutritional labels.
Chapter 3

3.1 Abstract

The aim of the study was to gain an understanding of Irish consumer attitudes towards ready-meals and current sodium issues in Ireland. A questionnaire was distributed to 357 consumers via convenience quota sampling to a range of nationalities in both rural and urban/city areas of Ireland. The survey revealed that a high proportion of respondents (45%; n=161) were worried about the amount of salt they consumed. Despite this 58% (n=207) stated they never look at the sodium/salt contents on nutritional labels with 68% (n=244) claiming that sodium/salt contents would never affect their buying choice. The survey also uncovered that 76% (n=270) of Irish consumers surveyed consider ready-meals to be high in sodium and 80% (n=285) consider them to be an unhealthy option. Despite this 50% (n=179) of respondents consumed a ready-meal at least once a week with a further 17% (n=59) consuming them 2-3 times a week. Of those that did consume ready-meals 78% (n=191) choose them due to their convenience. A total of 75% (n=269) of all respondents said they would choose a chilled ready-meal over its frozen counterpart. The reason for this being attributed to the fact that chilled ready-meals were perceived to be healthier (44%; n=158) and of better quality (54%; n=194) than their frozen counterparts. Results from this study highlighted the need for concerted actions involving consumers, manufacturers and retailers to reduce sodium levels in Irish ready-meals as despite being reasonably aware of the sodium issue consumers were not making informed choices to reduce sodium/salt consumption.

3.2 Introduction
The busy hectic lifestyles lived by many consumers today leaves little time to prepare meals from fresh ingredients in the home and in turn has led to a strong demand from consumers for products that are fresh, safe to eat, of good quality and most importantly convenient (Anonymous, 1994). By 2007 this consumer demand had led to a growth of 3.5% in the global ready-meal market to reach a value of $52.4 billion (Datamonitor, 2008a) with the Irish ready-meal market seeing similar growth with an average yearly rate of 3.2% between 2001-2006 (Datamonitor, 2008b). The term ‘ready-meals’ also often referred to as microwave meals, TV dinners or convenience meals, are generally accepted to be pre-packaged frozen or chilled complete meals which require little preparation apart from reheating prior to serving. These meals can include meat, poultry, seafood, pasta, rice and vegetable dishes and can be classified as traditional, continental, ethnic, vegetarian or low calorie/healthy option dishes (Henchion, 2000).

It is currently estimated that approximately 75% of the salt we consume comes from processed convenience foods (Dyer et al., 1997; Irish Heart Foundation, 2004; Grimes et al., 2008). A recent study conducted by Consensus Action on Salt and Health (CASH) in the UK highlighted particularly high levels of salt in many popular takeaways and ready-meals. One example from the study revealed a takeaway curry bought with all the extras could contain as much as 20.5g salt, while data published on levels of salt in ready-meals revealed that many popular meals were found to contain more than or at least 50% of the UK’s daily salt maximum of 6g a day (CASH, 2010). A similar study carried out in 2006 by the authors found that of 67 commercial ready-meals surveyed, 51 meals contained greater than 50% of an Irish adults recommended daily allowance (RDA) of 4g salt per day (FSAI Scientific Committee, 2005) and a further 8 meals were found to contain greater than 100% of an Irish adults RDA of salt in one single portion (Chapter 2). Health agencies worldwide are growing increasingly concerned about the high levels of sodium/salt consumed by the population as a substantial body of research now suggests that a high intake of sodium can lead to a rise in blood pressure with age and the development of hypertension in industrialised countries (Intersalt Cooperative Research Group, 1988; Antonios and MacGregor, 1996; MacGregor and Server, 1996; Law, 1997; Appel et al., 2001; MacGregor, 2004; FSAI, 2006) such as Ireland. Cardiovascular diseases
(CVD) including heart disease, stroke and related diseases are now the leading cause of death and disability worldwide (Lopez et al., 2006). Raised blood pressure from a systolic pressure above 115 mmHg is one of the most significant direct causes of cardiovascular disease (Lewington et al., 2002) accounting for 62% of all strokes and approximately 50% of all heart disease worldwide (World Health Organization, 2002). In Ireland CVD is now the single highest cause of death accounting for over two in five of all deaths (FSAI Scientific Committee, 2005). Increased sodium/salt intake has also been linked to instances of stomach cancer (Forman et al., 1991; Joossens et al., 1996; Wong et al., 2004), asthma (Burney, 1987; Carey et al., 1993), osteoporosis (Matkovic et al., 1995; Lin et al., 2003), oedema (MacGregor and de Wardener, 1997), kidney disease including kidney (renal) stones (Du Calier et al., 2002; Verhave et al., 2004; He et al., 2009; Borghi et al., 2002; Cappuccio et al., 2000), Ménière's disease (Beard, 2006) and diabetes (Ogihara et al., 2003; Hu et al., 2005) and is also indirectly a key influencing factor in several cases of obesity worldwide (He et al., 2008).

The effect of dietary salt on health has prompted many health organisations throughout the world to call for a reduction in dietary salt intakes. A technical report produced by the World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) in 2003 recommended the consumption of less than 5g salt (or < 2g sodium) per day as a population nutrient intake goal (World Health Organization, 2003). He and MacGregor (2002) conducted a meta-analysis based on 17 trials in hypertensives and 11 trials in normotensives predicted that a median reduction in sodium chloride intake to 6g/day may reduce average blood pressure by 7.1/3.9 mmHg in hypertensives and 3.6/1.6 mmHg in normotensives. It is estimated that an average reduction in blood pressure of this magnitude in the general population of most western countries would reduce the incidences of stroke by 24% and the incidence of ischemic heart disease by 18% (Stamler et al., 1989; Cook et al., 1995).

Despite many high profile campaigns by health agencies worldwide there seems to be little reduction in sodium intakes in industrialised countries; as apparent in Ireland where mean daily intakes of salt are still approximately 9-10g (twice the RDA) (FSAI Scientific Committee, 2005; Harrington et al., 2008). This may in part
be due to a lack of knowledge concerning consumer attitudes to salt in processed foods as information of this type could be used to formulate future strategies aimed at reducing salt intakes. Given the aforementioned popularity of ready-meals and their high salt levels the present study aimed to gather information regarding consumers’ attitudes towards ready-meals and current sodium levels in these foods in Ireland. The objectives of the questionnaire were to determine whether actual salt reductions in foods along with the increased presence of sodium/salt levels on nutritional labels and the many salt reduction campaigns in the media are having an impact on consumer attitudes to salt and ready-meal consumption.

3.3 Methods

3.3.1 Questionnaire Design
A questionnaire was designed comprising of 24 questions (23 multiple choice questions and 1 rank order question) addressing commonly occurring issues in the public domain in relation to both sodium and ready-meals. The questionnaire was divided into three sections. Section A (10 questions) dealt with salt consumption and related issues, and included a question which asked consumers to rank a number of commonly eaten foods (crisps per bag (25g), cornflakes per bowl (40g), 1 medium slice of bread (30g), ready-meal (per 100g)) in order from the food they perceived to contain the least amount of sodium/salt down to the food they perceived to contain the highest amount of sodium/salt. Section B (7 questions) dealt with ready-meal consumption and consumers perceived attitudes to ready-meals. Questions in this section probed respondents on the frequency of ready-meal consumption and reasons as to why they were consumed, whether they consider ready-meals to be high in salt and a healthy option, their preference for frozen or chilled ready-meals and if they consider one type to be to be healthier and of better quality than the other or do they perceive both types of meals to be the same. Section C (7 questions) was aimed at gathering demographic data on all respondents. Questions included gender, age, marital status, children, employment status, present health status and nationality.
3.3.2 Pilot Questionnaire
An initial pilot study using 30 questionnaires was administered to members (both male and female) of a local soccer club in east county Galway to evaluate the questionnaire for possible problems relating to phrasing of questions, possible omissions and any other difficulties experienced by respondents. After this initial study some minor modifications were made to the phrasing of questions and some answer options. The revised questionnaire was then administered to 20 staff members of the Ashtown Food Research Centre in Dublin to evaluate the modifications made and to check if any further modifications were needed. A three week test-retest reliability study conducted with the same 20 people revealed acceptable reliability scores of 0.789. Upon review of these results the questionnaire was deemed acceptable for the main study.

3.3.3 Questionnaire Administration
Questionnaires in the main study were circulated to 600 consumers in both rural (n = 300) and urban/city (n = 300) areas of Ireland between 2006 and 2007. Four locations in Ireland, two rural areas in the west of Ireland (Galway and Limerick) and two urban/city areas in the east of Ireland (Dublin and Wicklow) received 150 questionnaires each. Sample quotas based on population age were determined using the ‘Census 2006 Results’ obtained from the Central Statistics Office Ireland (2007). The following quotas for age were set: age 15-19 (9%), age 20-29 (21%), age 30-39 (20%), age 40-49 (17%), age 50-59 (14%) and age 60+ (19%). Questionnaires were administered via post and/or e-mail to 150 randomly selected consumers in each area. Mailing lists were obtained from local telephone directories in each area. All recipients of the consumer questionnaires received followed up reminder letters/e-mails.

3.3.4 Analysis of Data
Questionnaire responses were analysed using SPSS (Statistical Package for Social Sciences) for Windows version 14.0. Frequency counts, percentage of response and chi-squared tests were carried out. Level of significance difference between responses based on demographic data gathered was considered significant at P<0.05.
3.4 Results

Due to small sample sizes arising from certain sub-groups in the demographic data, readers of this study are advised to err on the side of caution when interpreting certain aspects of data reported. More specifically, the sub-groups of ‘separated/divorced’ (n=15), ‘living with partner’ (n=22), ‘working part time (<35hrs/week)’ (n=23), ‘homemaker’ (n=15), ‘retired & working part-time’ (n=1), ‘unemployed’ (n=1), and those of ‘fair health’ (n=17), all contain low samples sizes and therefore, care should be taken when interpreting results associated with these sub-groups.

3.4.1 Consumer Demographics

A total of 357 usable questionnaires (rural area, n=167; urban/city area, n=189) were returned giving an overall response rate of 59.5%. Table 3.1 illustrates the sample population age distribution (set quotas) as compared with the population age of persons living in Ireland. Consumer demographic data is presented in Table 3.2.

Table 3.1: Percentage of Sample Population Age Groups and Percentage of Age Groups Reported in The Irish Census 2006 Results

<table>
<thead>
<tr>
<th>Age Groups</th>
<th>Total No. of Respondents</th>
<th>% of Respondents</th>
<th>% of Irish Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-19</td>
<td>32</td>
<td>9.0</td>
<td>8.6</td>
</tr>
<tr>
<td>20-29</td>
<td>75</td>
<td>21.0</td>
<td>21.2</td>
</tr>
<tr>
<td>30-29</td>
<td>72</td>
<td>20.2</td>
<td>19.9</td>
</tr>
<tr>
<td>40-49</td>
<td>60</td>
<td>16.8</td>
<td>17.1</td>
</tr>
<tr>
<td>50-59</td>
<td>50</td>
<td>14.0</td>
<td>14.0</td>
</tr>
<tr>
<td>60+</td>
<td>68</td>
<td>19.0</td>
<td>19.2</td>
</tr>
<tr>
<td>Total</td>
<td>357</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

1 Percentage of Irish population age/age quotas were determined using the ‘Census 2006 Results’ obtained from the Central Statistics Office Ireland 2007.
Table 3.2: Demographic Data of Respondents (n=357)

<table>
<thead>
<tr>
<th>Gender</th>
<th>Children</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>45%</td>
<td>Yes</td>
<td>46%</td>
</tr>
<tr>
<td>Female</td>
<td>55%</td>
<td>No</td>
<td>54%</td>
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<table>
<thead>
<tr>
<th>Age</th>
<th>Employment Status</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>15 – 19</td>
<td>Work full time (≥ 35hrs/week)</td>
<td>58%</td>
</tr>
<tr>
<td>20 – 29</td>
<td>Work part time (&lt; 35hrs/week)</td>
<td>6%</td>
</tr>
<tr>
<td>30 – 39</td>
<td>Homemaker</td>
<td>4%</td>
</tr>
<tr>
<td>40 – 49</td>
<td>Student</td>
<td>23%</td>
</tr>
<tr>
<td>50 – 59</td>
<td>Retired</td>
<td>8%</td>
</tr>
<tr>
<td>60+</td>
<td>Retired &amp; working part time</td>
<td>0.5%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Marital Status</th>
<th>Present Health</th>
<th>Irish Nationality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single</td>
<td>41%</td>
<td>Yes</td>
</tr>
<tr>
<td>Married</td>
<td>37%</td>
<td>Excellent</td>
</tr>
<tr>
<td>Separated/Divorced</td>
<td>4%</td>
<td>Good</td>
</tr>
<tr>
<td>Widowed</td>
<td>12%</td>
<td>Fair</td>
</tr>
<tr>
<td>Living with partner</td>
<td>6%</td>
<td>No</td>
</tr>
</tbody>
</table>

3.4.2 Salt Consumption

Self assessed consumption of high sodium/salty foods by consumers revealed that 56% (n=198) claimed to sometimes eat a lot of salty foods, 27% (n=97) claimed they consumed a lot of salty foods while the remainder of respondents said they never or hardly ever (17%; n=62) eat salty foods. Significantly more males claimed to eat a lot of high sodium/salty foods (p<0.005) as well as those aged 15-19 (p<0.005), the unemployed (p<0.005), those who are single (p<0.005) and students (p<0.005). On the other hand significantly more people aged 60 and over (p<0.005), homemakers (p<0.005) and those who have children (p<0.005) never or hardly ever consume high sodium/salty foods. When consumers were asked about their discretionary salt usage 22% (n=80) declared they never add salt when preparing and cooking food, these people were typically female (p<0.005), aged 15-19 (p<0.005), considered themselves
in excellent or good health (p<0.01) and homemakers (p<0.01). The majority of consumers (46%; n=164) said it depended on the meal being prepared while 32% (n=113) said they always add salt when cooking and preparing meals regardless of the meal being prepared. Consumers who were unemployed (p<0.01), aged 60 and over (p<0.005), retired (p<0.01), male (p<0.005) and those who were retired and working part time (p<0.01) were significantly more likely to always add salt when preparing and cooking food. Almost one-half of consumers (46%; n=164) always add salt to their cooked food, 17% (n=60) never add salt to cooked food and the remaining 37% (n=133) sometimes add salt to cooked food. Homemakers (p<0.05), females (p<0.005), people aged 40-49 (p<0.005) and consumers who were employed full time (p<0.05) were significantly more likely to sometimes add salt to their cooked food. Of those that did add salt to their cooked foods 64% (n=190) added this salt after tasting the food, however, an alarming 42% (n=126) of consumers, who were typically male (p<0.05) and aged 40 and over (p<0.05) admitted they added salt to their cooked food before tasting it. Only 28% (n=100) of consumers correctly identified that the recommended dietary allowance (RDA) of salt for an Irish adult is 4g salt/day, the remaining respondents believed it ranged from 6g – 10g (Figure 3.1).

**Figure 3.1: What the Percentage of Respondents Consider to be the Recommended Dietary Allowance (RDA) of Salt for an Irish Adult**

![Bar chart showing the percentage of respondents considering different salt intakes as the RDA.](image)

Age of consumers significantly affected knowledge of the RDA of salt with those aged 15-19 (p<0.005) and 50-59 (p<0.005) most likely to get this figure correct.
Those aged 40-49 (p<0.005) believed the RDA of salt to be 8g/day while all other age groups (20-29; 30-39; 60+) considered it to be 6g/day. Almost half (48%; n=171) of those surveyed correctly identified 10-12g salt/day as the current average daily intake of salt in Ireland, 28% (n=98) believed it was 6-8g/day and a further 19% (n=69) considered it 14-16g salt/day. No significant differences were observed between the various socio-economic groups for the current average daily salt intake. Many consumers (42%; n=148) mistakenly thought that the majority of an Irish adults daily salt intake came from the salt they added themselves from the salt cellar and this assumption was significantly affected by gender, age, employment status and marital status, in particular men (p<0.01), aged 15-19 (p<0.005) or aged 60+ (p<0.005), students (p<0.005), the unemployed (p<0.005), the retired (p<0.005) and the widowed (p<0.05). However, 54% (n=193) correctly answered that the majority of an Irish adults daily salt intake came from factory made processed foods. Consumers who knew this were most likely to be either female (p<0.01), aged between 20 and 59 (p<0.005), employed full time (p<0.005), retired and working part time (p<0.005), single (p<0.05), married (p<0.05) and separated or divorced (p<0.005). When consumers were asked to rank four commonly eaten food items in order of increasing salt content only 4 out of 357 consumers surveyed put them in the correct order. Consumers correctly identified the ready-meal (per 100g) as containing the second highest amount of salt however, all other food items listed were perceived to contain either lower or higher amounts of salt in comparison to their actual salt contents (Table 3.3).

Table 3.3: List of Foods Consumers were Asked to Rank\(^1\) in Order of Increasing Salt Content in their Actual Order and Perceived Order

<table>
<thead>
<tr>
<th>Foods Listed</th>
<th>Actual order(^2)</th>
<th>Perceived Order(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bread, 1 medium slice (30g)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Crisps per bag (25g)</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Ready Meal (per 100g)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Cornflakes per bowl (40g)</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

\(^1\) Rank of 1 given to the least salty sample up to a rank of 4 to the saltiest sample. \(^2\) Correct order determined using Food Standards Agency (2002) McCance and Widdowsons The composition of Foods, 6\(^{th}\) Summary Edition. Cambridge: Royal Society of Chemistry. \(^3\) Order perceived by consumers based on percentage of consumers who awarded each rank to each food item.
One possible reason for this may be that when consumers were asked how often they looked at the salt/sodium contents on food nutritional labels only 6% (n=22) said they always look at the salt/sodium contents (Figure 3.2). The majority of respondents (58%; n=207) admitted they never look at the salt/sodium contents on food labels. Consumers who were aged 40-49 (p<0.005), married (p<0.005), separated or divorced (p<0.005), homemakers (p<0.005) and those who were retired and working part time were significantly more likely to occasionally (36%; n=128) look at the salt/sodium contents on food labels. All other demographic sub-groups claimed they never looked at the salt/sodium contents on food labels. When questioned further 68% (n=244) of respondents said that the salt/sodium content of a food would never affect their buying choices (Figure 3.2).

**Figure 3.2: Frequency Distribution (%) of Respondents who Consult Salt/Sodium Contents on Food Labels and the Percentage of Respondents who said these Salt/Sodium Contents Affect their Food Buying Choice**

![Graph showing frequency distribution of respondents consulting salt/sodium contents on food labels and those affected by it.]

Those who were separated or divorced were the only ones who were significantly more likely (p<0.05) to let the salt/sodium content on food labels affect their food buying choices, all other demographic sub-groups would never let the salt/sodium content of a food affect their buying choices. This result is surprising given the fact
that almost 45% (n=161) of those surveyed claimed they were worried about the amount of salt in their diets. Females (p<0.005), those aged 60 and over (p<0.005), consumers who have children (p<0.005), the widowed (p<0.005) and the retired (p<0.005) were significantly more likely to be worried about the amount of salt they consumed than all other demographic sub-groups.

**Figure 3.3: Percentage of Respondents who Consider Ready-Meals to be High in Salt/Sodium.**

![Graph](image)

### 3.4.3 Ready-Meal Consumption

In general consumers considered ready-meals to be high in salt (76%; n=270) and an unhealthy option (80%; n=285). Not one single consumer surveyed thought ready-meals were low in salt, with a mere 2% (n=8) of people saying only a small number of ready-meals were high in salt (Figure 3.3). Similarly not one person surveyed considered ready-meals to be a healthy food option with just 20% (n=72) believing them to be moderately healthy (Figure 3.4). Those who were separated or divorced were most likely to believe that ready-meals were moderately healthy (p<0.005) and that only a small number of ready-meals were high in salt (p<0.05). In addition, those who claimed to be of good health also perceived ready-meals to be moderately healthy (p<0.01) and considered only a small number of ready-meals to be high in salt (p<0.005). Despite these findings 50% (n=179) of respondents admitted to
consuming a ready-meal at least once a week with 17% (n=59) consuming them 2-3 times a week. While the majority of both men and women claimed they consumed a ready-meal once a week significant differences (p<0.005) were seen within this group with a larger proportion of women claiming they never consume ready-meals and a higher proportion of men claiming to consume ready-meals 2-3 times a week. Those aged 60 and over (p<0.005), the widowed (p<0.005), the retired (p<0.005) and the unemployed (p<0.005) stated they consume ready-meals 2-3 times a week. Whereas people who have children (p<0.005), are homemakers (p<0.005), those who are retired and working part time (p<0.005) and those who are married (p<0.005) were more likely to never consume ready-meals. However, it is important to note that approximately one third of consumers surveyed (31%; n=112) do not eat ready-meals. Of those that did consume ready-meals, 78% (n=191) choose them due to their convenience, other popular reasons given for eating ready-meals included ‘tasty’, ‘a wide range of choice’ and ‘value for money’. It is important to point out that although convenience was the primary reason for choosing a ready-meal, taste and therefore sensory acceptability was also a consideration (19%; n=47). Consumer demographics did not significantly affect the reasons for consuming ready-meals. When consumers were asked what type of ready-meal would they choose 75% (n=269) said they would choose a chilled ready-meal over its frozen counterpart, the reason for this being attributed to the fact that 54% (n=194) of those surveyed perceived chilled ready-meals to be of better quality than their frozen equivalent. A quarter of consumers (25%; n=88) said they would choose a frozen ready-meal over its chilled counterpart as they considered a frozen ready-meal to be healthier (20%; n=73) than a chilled ready-meal however, just 11% (n=38) considered them to be of better quality than their chilled counterparts. Consumers aged 60 and over (p<0.005), widowed consumers (p<0.005), the unemployed (p<0.005) and the retired (p<0.005) would all choose frozen ready-meals over chilled ready-meals. No significant differences were observed among the various demographic groups in terms of which type of ready-meal consumers perceived to be of better quality. However, the retired (p<0.005) and persons aged 60 and over (p<0.005) consider frozen ready-meals to be significantly healthier than chilled ready-meals. Just over one third of all respondents considered both frozen and chilled ready-meals to be of the same quality (35%; n=125) and healthiness (35%; n=126).
3.5 Discussion

3.5.1 Salt Consumption

The study revealed an apparent lack of knowledge among Irish consumers with regards to hidden salt in foods. The survey uncovered that only 27% of consumers believed they ate a lot of salty foods; this is despite the fact that the average Irish person consumes approximately 10g of salt per day (FSAI Scientific Committee, 2005; Harrington et al., 2008). Presently it is approximated that 75% of the salt consumed by Irish adults comes from processed convenience foods (Dyer et al., 1997; Irish Heart Foundation, 2004; Grimes et al., 2008) and although 54% of those surveyed correctly identified this, an alarming 42% of consumers thought that the majority of an Irish adults daily salt intake came from the salt they added themselves via the salt cellar. A recent Health Focus International (HFI) study as discussed by Nutrition Horizon (2010) found similar results with 55% of US consumers believing the best way to reduce the amount of sodium in their diets was to cut out table salt. Based on data related to sources of sodium/salt in our diets (Flynn et al., 1990; FSAI Scientific Committee, 2005; Harrington et al., 2008) the removal of discretionary salt from an Irish adults diet would still result in consumption of approximately twice the recommended dietary allowance of salt per day. According to Brown et al. (2009) who reported previously unpublished data from the INTERMAP study, which
included measurements of dietary sodium intake and urinary sodium excretions from 17 population samples from Japan, Peoples Republic of China, the UK and the USA, found excretion levels among people in the UK who made a conscious effort to reduce salt intake in their diets compared to those that didn’t make an effort showed no difference. In addition, dietary sodium intake of consumers in Japan and the USA showed only small decreases (18.9 and 13.6mmol/day respectively). These results emphasize the need for further reductions to be made to the salt content of foods worldwide as those consumers who are making conscious efforts to reduce salt in their diets are often still consuming in excess of the recommended dietary allowance and in reality are seeing little if any difference to the amount of salt consumed. Efforts should also be made to try and educate consumers about salt and the levels of it in foods. For example, in the present study when consumers were asked to rank four commonly eaten food items in order of increasing salt content, only 4 out of 357 consumers surveyed put them in the correct order. A new survey conducted by the Food Standards Agency (FSA) in the UK in October 2009 revealed that 77% of people are not aware that bread and breakfast cereals are among the daily foods that contribute the most salt to our diet and when asked to pick the top three foods that contribute the most salt to our diets from a list of ten, 73% picked crisps and snacks (FSA, 2009). The present study found similar results with crisps per 25g bag being perceived by respondents as the saltiest food item from the four presented when in fact it contained the second lowest amount of salt. This result again highlights the fact that Irish consumers appear to be unaware of the amount of hidden salt in processed foods. It is important to note at this point that although one medium slice of bread contained the least amount of salt of the four food items listed in this study it is in fact one of the foods that contributes the most amount of salt to our diets due to the volume of bread and bread products consumed by the average person in one day (FSA, 2009). In contrast to our findings, Purdy et al. (2002) found that when consumers in Northern Ireland were asked to rate the salt content of common processed foods, responses showed a considerable degree of accuracy with 52% scoring the products correctly in relation to salt level. Tilston et al. (1993) also reported that 52% of consumers they surveyed in the UK scored the salt content of a number of food items correctly. The UK has set the benchmark worldwide in terms of salt reduction strategies and consumer education on the salt issue and these studies by both Tilston et al. (1993) and Purdy et al. (2002) are an indication of their success.
with a greater awareness of the salt issue apparent in the UK and Northern Ireland. However, despite these findings results of the new survey conducted by the FSA in the UK in 2009 as discussed earlier reveals there still appears to be some confusion on this matter among consumers.

One possible reason why the consumers surveyed in the present study appeared so unaware of hidden salt in foods may be due to the fact that only 6% said they always look at the salt/sodium contents on their foods nutritional labels (Figure 3.1) with a further 36% occasionally checking this information. These figures are low in comparison to other studies which have reported that 25% (Norway), 29% (USA) and 65% (Australia) of respondents check the salt/sodium content on foods while shopping (Wandel and Bugge, 1996; Grimes et al., 2009; Nutrition Horizon, 2010). Despite the fact that 42% of those surveyed said they would always or occasionally look at the salt/sodium contents on nutritional labels 58% said they never looked at this information and a total of 68% of respondents claimed that this information would never affect their food buying choices. This may be due to consumers having a poor comprehension of nutritional information on foods as reported by Tessier et al. (2000), who found that those surveyed could not relate the numerical amount of nutrients on nutritional labels to a verbal or written description. Only a mere 4% of respondents in the present study claimed that the salt/sodium content on a nutritional label would always affect their buying choice. This finding is in agreement with a study carried out by Higginson at al. (2002) who found that nutritional label information as a whole was used during the choice of only 4.2% of products purchased during everyday shopping trips and that the sodium/serving information on labels was accessed a total of two times during the study (in comparison to other nutritional information on labels such as fat/100g and energy/100g which were both accessed over 130 times). A survey of 474 consumers in Melbourne, Australia conducted by Grimes et al. (2009) reported that 65% of participants were unable to correctly identify the relationship between salt and sodium and found that 40% thought that salt and sodium were in fact the same substance. Consumers who are simply not aware of the connection between sodium and salt may in fact read the sodium content on the food label but due to lack of information would not connect it with salt content and/or may indeed think it is the salt content. Although the number of food processors who place ‘salt equivalent’ values on food labels has increased in
recent years there are still a large number of manufacturers who do not do this and only place the sodium contents on the label. This may explain why 10% of those in the present study who claimed to look at the salt/sodium contents on nutritional labels have never let these values affect their buying choice.

The study revealed that almost 50% of those surveyed claimed they were worried about the amount of salt in their diet. Despite this 32% said they always add salt when preparing and cooking food, 46% claimed to always add salt to their cooked food and 42% of those surveyed added this salt before tasting the food. These findings are similar to those found in ‘SLAN 2007: A survey of lifestyles, attitudes and nutrition in Ireland’, where it was reported that 30% of the 10,364 respondents surveyed ‘always’/‘usually’ added salt while cooking and 32% added it to their cooked food at the table (Harrington et al., 2008). In spite of approximately half of the people in the present study being worried about the amount of salt in their diet they were still reaching for the salt cellar on a regular basis. These results highlight the need for further health education or perhaps new approaches to educating consumers as to the detrimental effects of high salt intakes; however, it is vital that this education is supported by manufacturers and retailers in the provision of low salt alternatives which contain clear and easy to understand nutrition labelling.

3.5.2 Ready-Meal Consumption

The study revealed that ready-meals appear to have an unhealthy negative image among consumers as it was found that 76% of respondents considered ready-meals to be high in salt and a further 80% believed them to be unhealthy. A study carried out by Geeroms et al. (2008) revealed a similar negative attitude towards ready-meals and also found a negative attitude towards the statement that ‘ready-meals are nutritious’. Despite this negative image ready-meals remained a very popular food choice among respondents in the present study. Results showed that 50% of respondents admitted to consuming a ready-meal at least once a week. De Boer et al. (2004) reported similar findings for Irish consumers with an average purchase frequency among 1024 food purchasers of once a week. Prim (2007) reported a lower consumption frequency in Sweden with 22% of those surveyed consuming a ready-meal once a week and found that a further 19% of respondents consumed ready-meals twice a week. The present
study again reported similar findings with 17% of respondents consuming ready-meals 2-3 times a week. The current study also found significant differences between men and women in relation to frequency of ready-meal consumption. While the majority of both genders consumed a ready-meal once a week, significant differences were seen with significantly more women claiming to never consume ready-meals and significantly more men consuming them 2-3 times a week. Today women still often carry the sole responsibility for preparing and cooking meals in the home and therefore, do not rely on convenience style ready-meals to the same extent as men who may not have the same confidence and/or cooking skills to prepare homemade meals from fresh ingredients (Murcott, 2000; Reed et al., 2003).

Convenience was the principal reason cited by respondents across all demographics for consuming ready-meals. This result is not surprising especially in today’s hectic busy society where consumers no longer appear to have the luxury of time to prepare meals from fresh ingredients. Many previous studies have found similar results with time pressures and convenience being cited as the main reason for both purchase and consumption of ready-meals (Madiill-Marshall et al., 1995; Verlegh and Candel, 1999; Reed et al., 2003; De Boer et al., 2004; Ahlgren et al., 2005; Prim, 2007). The sensory properties of the meals were also found to be important with one fifth of those surveyed mentioning ‘taste’ as a reason for their consumption. This is an important point to note as no matter how convenient a food is in terms of preparation and/or cooking if it does not taste acceptable to the consumer they will not repurchase, a view shared by Katz (1999). Reed et al. (2000) reported that despite convenience being named the primary reason for choosing chilled ready-meals, the products taste and flavour qualities had a significant impact on food preference and the ensuing consumption decisions.

The present study indicated that over three quarters of those surveyed would purchase a chilled ready-meal over a frozen ready-meal. Reed et al. (2000) found that one of the reasons cited by consumers for not purchasing chilled ready-meals was that they purchase frozen ready-meals. Age seemed to have an important influence on the type of meal purchased with more 20-29 and 30-39 year olds choosing chilled ready-meals. From the age of 40 onwards the number of people choosing chilled ready-meals decreased and the number choosing frozen ready-meals increased. Reed et al.
(2003) found similar results stating that younger respondents particularly the 25-34 year age group are significantly more likely to consume chilled ready-meals. Moisio et al. (2004) also found that younger people tended to be more positively disposed toward the use of ready-made products. These age groups tend to lead busy lifestyles where the demands for convenience foods such as complete meals like ready-meals are high.

Overall chilled ready-meals were deemed to be of better quality (54%; n=194) and healthier (44%; n=158) than frozen ready-meals by respondents. A Mintel research report into ‘Ready-meals in the UK’ also found frozen ready-meals were perceived as lower quality products and less healthy than chilled ready-meals (Mintel, 2003). However, of the 25% who would buy frozen ready-meals 20% perceived them to be healthier than their chilled counterpart. Those aged 60 and over and those who were retired were significantly more likely to buy frozen ready-meals and also believed them to be significantly healthier than chilled ready-meals. Both these demographic groups are associated with more senior or elderly consumers who are possibly more familiar and therefore, more trusting of frozen ready-meals. Their popularity may also be attributed to their prolonged shelf life and the fact that they can be bought in bulk and stored for longer periods than chilled ready-meal, reasons which may be favoured by those who are less mobile due to age.

Despite the majority of consumers claiming they would purchase a chilled ready-meal over its frozen equivalent the study found 35% of those surveyed considered both frozen and chilled ready-meals to be the same in terms of perceived product healthiness and overall meal quality. Consumers who perceive both chilled and frozen ready-meals to be equal in terms of product quality and perceived healthiness are perhaps drawn by the sensory appeal of these products and this may explain why these consumers would then choose one meal type over the other.

3.6 Conclusion
Despite many salt reduction campaigns in Ireland it would appear from the present study that not all consumers receiving this information have absorbed it or acted positively to reduce their salt consumption. This was highlighted many times
throughout the study with consumers being unable to choose the correct RDA for salt intake for an Irish adult and incorrect ranking of foods based on salt content. A high proportion of respondents thought the majority of their daily salt intake came from the salt cellar. Almost 60% never look at salt/sodium contents on food labels. It would appear that more high profile targeted campaigns and education programmes are needed to raise salt awareness in Ireland as these campaigns appear to have a positive impact in other countries especially the UK. While a high proportion of respondents considered ready-meals to be an unhealthy option due to their high salt content, most still consumed them at least once a week. It is vital therefore that the food industry continues to reformulate high salt products to lower salt contents and to continually introduce low salt products onto the market with clear and easily understandable labelling for the common good of all consumers.
Chapter 4

4.1 Abstract

The present study investigated the effects of current salt reduction strategies on the sensory acceptability of 3 reduced salt frozen ready-meals. Initial sensory trials incorporating paired comparison, triangle and preference tests were used to examine the effect of gradually lowering salt levels in chicken curry, chilli con carne and lasagne ready-meals. Salt levels in chicken curry ready-meals can be reduced by 33%, by 50% in chilli con carne ready-meals and by 29% in lasagne ready-meals. Therefore, the maximum amount of salt which could be removed from the ready-meals via a gradual salt reduction strategy equated to a 0.2% salt reduction in chicken curry ready-meals, a 0.5% salt reduction in chilli con carne ready-meals and a reduction of 0.3% salt in lasagne ready-meals. A range of commercially available salt substitutes and flavour enhancers were subsequently sourced and incorporated into each of the lowest salt ready-meals. Sensory analyses including triangle, paired comparison and preference tests revealed that the incorporation of the amino acid and potassium chloride based salt substitute, AlsoSalt®, into chicken curry ready-meals allowed salt levels to be reduced to a final concentration of 0.2%, an overall salt reduction of 66%, without panellists detecting a noticeable difference in taste. Salt reductions of 60% were achieved in chilli con carne ready-meals via the addition of Provesta® 512, a nucleotide yeast extract. Finally, the addition of the popular salt substitute potassium chloride (KCl) into lasagne ready-meals resulted in salt levels being reduced to a final concentration of 0.55% salt, an overall salt reduction of 48%. Concerns over the use of KCl based salt substitutes imparting bitter notes at the levels used in this study for all three ready-meals were not justified.

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4.2 Introduction
Reduction of salt (sodium chloride) in foods is now recognised as one of the top 14 challenges facing the food industry today (Katan et al., 2009). While flavour remains a critical factor influencing an individual’s acceptance of a food, a significant reduction in the salt content of a food can impact negatively on flavour and hence, consumer acceptability. The challenging lifestyles lived by today’s consumers leaves little time to prepare meals from fresh ingredients in the home. This has led to a strong demand from consumers for products that are convenient and quick to prepare in addition to being fresh, tasty and safe to eat (Anonymous, 1994; Dötsch et al., 2009). As a result ready-meals have become increasingly popular with consumers in recent times; however, evidence indicates that these meals contain high levels of salt (FSA, 2003; The Guardian, 2010). Health agencies throughout the world are growing increasingly concerned with this high intake of non-discretionary sodium from salt and sodium containing additives used in the manufacture of these meals. A substantial body of evidence now exists to suggest that high dietary sodium intake, consumed primarily in the form of sodium chloride, is an important causal factor in the rise in blood pressure with age in industrialised countries (Intersalt Cooperative Research Group, 1988; Antonios and MacGregor, 1996; MacGregor and Server, 1996; Law, 1997; Appel et al., 2001; MacGregor, 2004; FSAI Scientific Committee, 2005). High blood pressure is the main cause of strokes and a major cause of heart attacks, two of the most common causes of death and illness worldwide (Ruusunen and Puolanne, 2004; Lopez et al., 2006). A high dietary sodium intake has also been linked with other conditions, such as stomach cancer (Forman et al., 1991; Joossens et al., 1996; Wong et al., 2004), asthma (Burney, 1987; Carey et al., 1993), osteoporosis (Matkovic et al., 1995; Lin et al., 2003), oedema (MacGregor and de Wardener, 1997), kidney disease including kidney (renal) stones (Cappuccio et al., 2000; Borghi et al., 2002; Du Cailer et al., 2002; Verhave et al., 2004; He et al., 2009), Ménières disease (Beard, 2006) and diabetes (Ogihara et al., 2003; Hu et al., 2005).

A technical report produced in 2003 by the World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO), recommended the consumption of less than 5g salt (or <2g sodium) per day as a population nutrient intake goal (World Health Organisation, 2003). In Ireland, the Food Safety Authority of Ireland (FSAI) has endorsed these recommendations, with
the aim of reducing the average population intake of salt down to 6g per day as an achievable target. However, current levels of salt consumption are much greater than this with approximately 8-10g being consumed daily by the average Irish consumer (FSAI Scientific Committee, 2005; Harrington et al., 2007; Perry et al., 2010). Given the high levels of salt in ready-meals available on the Irish market, as reported in Chapter 2, and the popularity of these items, as reported in Chapter 3, it is highly probable that salt from ready-meals make a highly significant impact on consumption levels. Therefore, the formulation of strategies for the reduction of salt in ready-meals is highly desirable. However, neither consumers nor manufacturers are willing to accept strategies which negatively impact on the sensory acceptability of the final product, thus, an in-depth examination of the effect of salt reduction is critical.

Unlike the other basic tastes such as sweet, bitter and umami, which have many triggers, the basic tastes of sour and salt are each generated by a single chemical agent. Sour taste is elicited by protons (Ugawa, 2003), however, only sodium chloride is associated with the unique taste of salt and its ability to intensify and alter the flavours of other ingredients present in food (Hutton, 2002). Various different techniques have been adopted by the food industry as they attempt to reduce salt contents in their products. The first involves incremental reductions in the amount of salt added to food formulations, over an extended period, until the required low salt level is achieved. Evidence suggests that as the salt reductions are gradual, the sensory attributes of the food appear unchanged to the consumer as their salt appetite adjusts to the decreased salt level over time (Bertino et al., 1982). However, despite this method being popular within the food industry, a level of salt reduction will ultimately be reached after which a loss in overall flavour will be noticed by consumers (Kilcast and den Ridder, 2007). To overcome this, the second popular approach involves an immediate removal of salt present in the product, with the resultant loss in salt taste compensated for through the use of substitutes that deliver the required flavour by other means. The use of salts which replace the cation Na$^+$ with potassium, calcium, magnesium or ammonium, and by anions such as phosphates or glutamates (Kilcast and den Ridder, 2007; Reddy and Marth, 1991) is routine, however, each is not without its drawbacks. For example, the most popular of these, potassium chloride, has been shown to impart bitter and/or metallic notes to foods when used at high levels (Fitzgerald and Buckley, 1985; Desmond, 2006).
Other products often used include salt or flavour enhancers, which enhance or modify the original taste and/or aroma of a food and can generate a powerful flavour within a product which is not necessarily a characteristic salty flavour (Gillette, 1985; Pszczola, 2004). Bitter inhibitors have also been used to mask or block the bitter taste associated with the use of potassium chloride. More recently, flake or dendritic type salts, which are sodium chloride salts where the crystals are star-like or branched instead of the normal cubic structure, are used as they are said to impart a sharper salty taste at a lower level (Kilcast and den Ridder, 2007).

The present study aimed to assess the impact of both salt reduction strategies on the sensory acceptability of three popular frozen ready-meals, chicken curry, chilli con carne and lasagne, with a view to providing manufacturers with recommendations as to the best strategy to consider when attempting to reduce salt levels in ready-meals.

4.3 Materials and Methods

4.3.1 Screening of Sensory Panellists
Thirty five staff members of the Ashtown Food Research Centre (AFRC), Dublin, consisting of 20 females and 15 males, aged between 22 and 65 years, participated in the sensory panels. All panellists were untrained when recruited but had partaken in previous taste panels within the AFRC. Prior to participation, panellists were presented with a series of coded salt solutions, with concentrations of 0.4, 0.6, 0.8, 1.0 and 1.5% (w/v) and asked to rank the solutions in order from saltiest to least salty. Panellists were accepted for further testing based on those who ranked the samples in the correct order or those who inverted an adjacent pair only. A total of 30 panellists, 18 females and 12 males, were selected for the remainder of the trial.

4.3.2 Sensory Analyses Methods Used
All sensory analyses panels were conducted on separate days (1-7 days apart), at the same time each day (before 13:00h) and varied in length from 5-15mins. All gradual salt reduction sensory analyses were completed and conducted prior to the salt
substitute sensory analyses. Sensory tests were carried out in the following order (A) paired comparison test (B) triangle test (C) preference test (D) ranking test. Sixty responses were the norm for all tests i.e. 2 samples x 30 panellists, 3 samples x 20 panellists, etc. Thirty panellists (18 females, 12 males; aged between 22 and 65 years) took part in all paired comparison and preference tests, twenty panellists (12 females, 8 males; aged between 24 and 57 years) took part in all triangle tests and fifteen panellists (8 females, 7 males; aged between 24 and 57 years) took part in all ranking tests.

4.3.2.1 Paired Comparison Test
A paired comparison test was conducted to determine if the ready-meals differed in relation to one specific named attribute i.e. salty taste. Each of the reduced salt ready-meals were individually compared to their regular salt commercial counterpart using the procedure described by Meilgaard et al. (1991). Thirty panellists received two coded samples, one regular salt sample (A) and one of the reduced salt samples (B). Equal numbers of the combinations AB and BA were prepared and presented at random among the panellists. Panellists were asked to taste each sample and determine which sample they perceived to be saltier. A section was included for panellists to leave comments on any aspect of the test. Thirty panellists were also asked to individually compare each of the salt substitutes incorporated into the lowest salt ready-meal with their regular salted counterpart, where panellists were again asked to taste each sample and identify which sample they perceived to be the saltier sample.

4.3.2.2 Triangle Test
Triangle tests were carried out to determine if an overall sensory difference existed between two samples i.e. between the regular salted commercial ready-meal and each of the individual reduced salt ready-meals produced. Three coded samples were presented to twenty panellists, two regular salt samples and one reduced salt sample or one regular salted sample and two reduced salt samples. Equal numbers of the combinations ABB, BAA, AAB, BBA, ABA and BAB, where A was the regular salted sample and B was the reduced salt sample, were prepared and presented at
random among the panellists. Panellists were informed that two of the samples were the same and one was different. Panellists were asked to taste the three samples and to identify the odd or different sample. A section in the questionnaire was included for panellists to leave comments on any aspect of the test. This sensory test was also used to compare each of the salt substitutes incorporated into the lowest salt meal with the regular salt ready-meal.

4.3.2.3 Preference Test
A basic preference test was carried out. Thirty panellists were presented with two coded samples, one regular salt sample (A) and one of the reduced salt samples (B), or one regular salt sample (A) and one of the salt substitute samples (B). Equal numbers of the combinations AB and BA were prepared and presented at random among the panellists. Panellists were asked to taste the two samples and to indicate which sample they preferred. A section was included for panellists to comment on any aspect of the test.

4.3.2.4 Ranking Preference Test
Fifteen panellists were presented with a total of six coded chicken curry and chilli con carne samples (only four coded samples presented for lasagne); one regular salt sample and one sample of each of the five salt substitute ready-meals (three salt substitute ready-meals for lasagne). Panellists were asked to taste the samples and rank them in their order of preference from the highest ranked sample, which received a rank of 6 (or a rank of 4 in the case of lasagne), down to the sample they least liked which received a rank of 1. Therefore, the sample receiving the lowest overall rank total will be the sample least preferred by panellists while the sample with the highest overall rank total will equal the sample panellists most preferred. A section was included for panellists to comment on any aspect of the test.

4.3.2.4 Acceptability Test
The consumer acceptability of two frozen lasagne ready-meal samples (one commercially available regular salt sample and one reduced salt sample with added
KCl) were evaluated by one hundred and seventy-five untrained consumers, all of whom were regular consumers of ready-meals. Consumers had not partaken in any previous reduced salt ready-meal sensory analysis and ranged in age from 19 to 70 years of age (99 female, 76 males). Four sessions (n=25-50) were conducted over one month with analysis being conducted at the same time and on the same day each week. Consumers were individually asked to blind taste test both coded samples and rate their acceptability using the following 9 point hedonic acceptability scale; 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, 1 = dislike extremely. Consumers were also asked if they perceived the samples to be the ‘same/identical’ or ‘different’.

4.3.3 Ready-Meal Sample Preparation
Two 45kg batches of frozen lasagne ready-meals and two 48kg batches of frozen chilli con carne frozen ready-meals were prepared by Dawn Fresh Foods Ltd., Fethard, Co. Tipperary, Ireland, according to their standard industrial protocol. One batch of each ready-meal was formulated to contain regular commercial levels of salt (lasagne-1.05% w/w; chilli con carne-1.0% w/w) whereas the second batch of ready-meals were formulated to contained only residual salt levels (lasagne-0.55% w/w; chilli con carne-0.4% w/w). These samples were packaged in 375g portions of lasagne and 500g portions of chilli con carne, blast frozen and stored at -18°C upon receipt.

‘Model’ chicken curry ready-meals were manufactured at test kitchen scale at the Ashtown Food Research Centre, Dublin 15, Ireland following industrial protocols and industrial recipes received from Dawn Fresh Foods. Twenty kilograms (20kg) of chicken breast fillets were sourced from a local Irish supplier (Carton Brothers, Dublin, Ireland). The fillets were separated into 2kg lots, vacuum packaged (Vac-Star S 220, Vicquip Ltd., International Food Machinery Suppliers, Clondalkin, Dublin 22) and blast frozen at -30°C and stored at -18°C until required. The day before processing, the required amount of chicken was removed from frozen storage and thawed overnight at 4°C. On each processing day approximately 2kg lots of chicken
breast were cut into cubes of 2-3cm in size and transferred to a stainless steel saucepan containing 4 litres of water. The saucepan was covered and the cubes were heated at 70-80°C for 20-25 minutes or until the internal temperature of the chicken had reached 75°C and maintained at this temperature for 2 minutes. Eight litres of water was added to a separate saucepan into which 2kg of a ‘no salt curry mix’ (AllinAll Ingredients, Dublin 12) was slowly added with constant stirring. The ingredient declaration for this ‘no salt curry mix’ is given in Table 4.1.

Table 4.1: Ingredient Declaration of No Salt Curry Mix Used in the Manufacture of ‘Model’ Chicken Curry Ready-Meals

<table>
<thead>
<tr>
<th>Ingredients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dextrose</td>
</tr>
<tr>
<td>Sugar</td>
</tr>
<tr>
<td>Modified Starch (E1422)</td>
</tr>
<tr>
<td>Milk Powder</td>
</tr>
<tr>
<td>Curry Powder</td>
</tr>
<tr>
<td>Tomato Powder</td>
</tr>
<tr>
<td>Maltodextrin</td>
</tr>
<tr>
<td>Onion Powder</td>
</tr>
<tr>
<td>Ground Spices</td>
</tr>
<tr>
<td>Antioxidant (E330)</td>
</tr>
</tbody>
</table>

The curry sauce was then heated to 75°C and held at this temperature for 2 minutes. The chicken was drained and slowly mixed into the curry sauce and heated for a further 5-10mins. One half of each batch prepared were pre-packed in trays [110 x 150 x 55mm (Dynopak Ltd, Dublin)] containing 250-300g of chicken curry using a MAP machine (MECApac 500 semi-automatic packaging machine, rue Diderot, Bagnolet, France) in air. The second half of each batch of chicken curry then had 0.4% aqueous salt solution added to produce a commercially equivalent range of regular salt chicken curry ready-meals. These meals were then packed and sealed as
per reduced salt meals above. All sealed chicken curry packs were blast frozen and placed in the -18°C freezer until required for testing.

4.3.4 Preparation of Samples for Sensory Analyses

The day before sensory evaluation, the required number of regular and reduced salt ready-meals were removed from the freezer and thawed over night at 4°C. A 30% salt solution was prepared and appropriate volumes of this solution were added to the chicken curry, chilli con carne and lasagne ready-meals, to produce a range of reduced salt meals with salt concentrations of 0.2, 0.4, 0.8, 1.0 and 1.5% salt for chicken curry ready-meals; 0.4, 0.5, 0.6, 0.8, 1.25 and 1.5% salt for chilli con carne ready-meals; and 0.55, 0.65, 0.75 and 0.85% salt for lasagne ready-meals. For chicken curry and chilli con carne ready-meals this was achieved by the direct addition of the salt solution into the reduced salt meals which were subsequently thoroughly mixed to ensure a homogeneous distribution of spice. However, for the lasagne ready-meals aqueous salt solutions were added to the bolognese-type meat sauce layers. This was achieved by separating out the individual layers of each reduced salt lasagne ready-meal and placing the meat sauce layers from each meal into separate trays [110 x 150 x 60mm (Dynopak Ltd, Dublin)]. The contents of each tray were thoroughly mixed to ensure a homogeneous distribution of salt. Each meal was then re-assembled into their original tray. Following the addition of salt each meal was held at 4°C for 1-2 hours prior to testing to ensure the salt had equilibrated fully throughout the meal. On the day of analysis for both chicken curry and chilli con carne approx. 250g of rice (Uncle Ben’s® Long Grain Rice, Mars Foodservices, San Antonio, USA) and 500mls of water were placed into a saucepan and cooked for 10mins or until all the water had been absorbed. The cooked rice was then placed into individual circular foil cases (50 mm diameter). The chicken curry or chilli con carne meals were cooked for 7 and 10 minutes, respectively, on full power (850watts) in a microwave oven and were then distributed evenly into the foil cases containing the rice. Lasagne ready-meals were prepared for analysis by cutting the meal into eight equal portions within the tray and then cooking for 12 minutes on full power in a microwave oven (850watt) as per manufacturer’s instructions. Equal portions of the meals were subsequently distributed into individual circular foil cases (50mm diameter). Samples were presented to panellists in a random order on white paper
plates, labelled with three digit random codes derived from the Compusense® five software (Compusense Inc., Ontario, Canada). Panellists were presented with the samples in individual testing booths adjacent to the sample preparation area, equipped with serving windows, controlled lighting and computers for ballot presentation and data collection using Compusense® five software. Plastic cutlery, napkins and water, to palate cleanse were also provided.

<table>
<thead>
<tr>
<th>Salt Substitutes/Flavour Enhancer</th>
<th>Active Ingredients</th>
<th>Ready-Meal Used In</th>
</tr>
</thead>
<tbody>
<tr>
<td>KCl</td>
<td>KCl</td>
<td>Chicken curry, chilli con carne, lasagne</td>
</tr>
<tr>
<td>AlsoSalt®</td>
<td>KCl and L-Lysine</td>
<td>Chicken curry, chilli con carne, lasagne</td>
</tr>
<tr>
<td>Provesta® 029</td>
<td>KCl &amp; Autolyzed Yeast</td>
<td>Chicken curry, chilli con carne, lasagne</td>
</tr>
<tr>
<td>Provesta® 027</td>
<td>Autolyzed Yeast</td>
<td>Chicken curry</td>
</tr>
<tr>
<td>Provesta® 000</td>
<td>Whole Cell Yeast</td>
<td>Chicken curry</td>
</tr>
<tr>
<td>Provesta® 512</td>
<td>Autolysed Yeast Extract</td>
<td>Lasagne, chilli con carne</td>
</tr>
<tr>
<td>Provesta® 001</td>
<td>Whole Cell Yeast</td>
<td>Chilli con carne</td>
</tr>
</tbody>
</table>

### 4.3.5 Salt Substitute Addition

For the salt substitutes study a selection of commercial salt substitutes and flavour enhancers were sourced from AllinAll Ingredients, Dublin and AlsoSalt, Maple Valley, Washington (Table 4.2). Each salt substitute/flavour enhancer was prepared as a 30% solution in water. The day before testing the required number of ready-meals were removed from frozen storage and thawed overnight at 4°C. Salt substitutes were added to each of the lowest salt ready-meals (0.2% salt chicken curry ready-meal; 0.4% salt chilli con carne ready-meal; 0.55% salt lasagne ready-meal) at a level of 0.4, 0.5 and 0.5% respectively, using the procedure outlined above for real
salt samples. Sample preparation and presentation was as described for real salt samples.

4.3.6 Determination of the Sodium Content by Atomic Absorption Spectrometry
The sodium contents of all ready-meal samples used in the present study were determined using the method described in Chapter 2 (section 2.3.2, page 42).

4.3.7 Data Collection and Statistical Data Analyses
Compusense® five software (Compusense Inc., Ontario, Canada), a computer software package for sensory analyses data collection was used during the course of this study. The software was used to create questionnaires, present questionnaires to panellists according to an experimental design plan and to collect and analyze all data. All statistical analyses were performed using the Compusense® five software (Compusense Inc., Canada). All preference and paired comparison sensory analyses tests carried out were recognised as ranking tests by the software and therefore, conducted crosstabulation (samples by ranking order) and percent crosstabulation, Friedman analysis of rank, chi-square and Tukey’s Honestly Significant Difference (HSD) for rank (10%, 5%, 1%, automatic) were carried out on these data. Triangle test data were analysed as frequency counts with Binomial probabilities (number of correct responses required for significance, and p-value) and crosstabulation of responses. Acceptability test data were analysed using crosstabulation and percentage crosstabulation, summary statistics (counts, medians, means and standard deviations) and 2-way Analysis of Variance (ANOVA).

4.4 Results and Discussion

4.4.1 Impact of Incremental Salt Content Changes on the Sensory Properties of Frozen Ready-Meals

4.4.1.1 Chicken Curry
From Table 4.3 it can be seen that in the paired comparison test panellists detected a significant difference in saltiness between the regular salt meal (0.6% salt) and meals
with salt concentrations of 0.8%, 1.0% and 1.5% (p<0.005). Panellists could not detect a difference in salty taste between the regular salt meal and ready-meals with final salt levels of 0.2% and 0.4% (Table 4.3, p>0.05). However, while panellists found no significant difference in saltiness between the regular salt ready-meal and the 0.2% reduced salt ready-meal (p>0.05), some panellists commented that there was a slight ‘sweet’ taste/aftertaste in this chicken curry ready-meal, thus, indicating a noticeable difference. This was also the case during the triangle tests. Results from the triangle test showed that panellists detected a significant difference in saltiness between the regular salt ready-meal and the 1.0% and the 1.5% ready-meals (p<0.005). Table 4.3 also illustrates that there was no significant difference between the regular salt ready-meal and the reduced salt ready-meals with final salt concentrations of 0.8%, 0.4% and 0.2% (p>0.05). In agreement with results from the paired comparison test, this indicates that a gradual reduction in salt levels from 0.6% to 0.4% was possible without panellists detecting a difference in both overall and salty taste. It is also interesting to note that panellists were unable to detect a difference in salt levels between control samples (0.6 % NaCl) and samples with 0.8% NaCl. This may be a direct result of the high levels of salt added to processed foods in recent years which has resulted in some consumers’ palates becoming slowly recalibrated to accept high salt products. Results from the preference test (Table 4.3) show that panellists did not detect a significant difference (p>0.05) between the regular salt ready-meal (0.6% salt) and any of the reduced salt ready-meals (0.2, 0.4, 0.8, 1.0 and 1.5% salt) in terms of preference. Other studies have shown that the acceptability of a complex food may remain relatively stable if only one attribute is manipulated, as the overall change in the complex product is small (Conner and Booth, 1992; Ainsworth et al., 1993; Laurila et al., 1996; Perlmutter et al., 1997). Therefore, in a complex food such as a ready-meal reducing the salt content may not affect consumer preference as salt taste may not be the main factor behind preference for the product.
Table 4.3: Probability Levels Associated with Sensory Analyses of Chicken Curry Ready-Meals with Salt Levels of 0.2-1.5% (w/v)

<table>
<thead>
<tr>
<th>Ready-Meal Salt Concentration</th>
<th>Paired Comparison Test</th>
<th>Triangle Test</th>
<th>Preference Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2%</td>
<td>0.465</td>
<td>0.092</td>
<td>0.068</td>
</tr>
<tr>
<td>0.4%</td>
<td>0.715</td>
<td>0.521</td>
<td>0.465</td>
</tr>
<tr>
<td>0.8%</td>
<td>0.001</td>
<td>0.339</td>
<td>0.144</td>
</tr>
<tr>
<td>1.0%</td>
<td>0.001</td>
<td>0.000</td>
<td>0.465</td>
</tr>
<tr>
<td>1.5%</td>
<td>0.000</td>
<td>0.000</td>
<td>0.465</td>
</tr>
</tbody>
</table>

1Results of Compusense® five statistical analyses for comparison of regular salt chicken curry ready-meals with reduced salt chicken curry ready-meals with salt added at levels from 0-1.3%.

4.4.1.2 Chilli Con Carne

The effect of gradually reducing and increasing the salt content on the sensory acceptability of the ready-meal, was determined using paired comparison and triangle tests, results of which are presented in Table 4.4. Results indicated that during the attribute specific paired comparison test, panellists detected a significant difference in salty taste between the regular salt meal (1.0% salt) and meals with salt concentrations of 0.4, 1.25 and 1.5% (p<0.005). However, at reduced salt concentrations of 0.5, 0.6 and 0.8% panellists could not detect a difference in salty taste between the regular salt meal and these particular reduced salt meals (p>0.05). Results from the triangle test were similar, with panellists correctly identifying the odd/different sample when the regular salt ready-meal and reduced salt meals with 0.4, 1.25 and 1.5% were compared (p<0.005). However, in contrast to results from the paired comparison test, during the triangle test panellists detected a significant difference between the regular salt meal and the reduced salt meal containing 0.5% salt (p<0.005). Panellists were again unable to detect a significant difference between the regular salt chilli con carne ready-meal and the reduced salt chilli con carne meals containing salt concentrations of 0.6 and 0.8% (p>0.05). Results from the triangle test combined with previous results from the paired comparison test, suggest that it is possible to remove between 0.2 and 0.4% salt from a chilli con carne ready-meal without a noticeable difference in taste being detected. These findings support the gradual salt reduction program endorsed by many organisations including the Food Safety Authority of Ireland.
(FSAI) (FSAI Scientific Committee, 2005), the Food and Drink Industry Ireland (FDII) (IBEC, 2005), and the World Action on Salt and Health (WASH) (He et al., 2010), and can potentially be applied to other ready-meal products within the food industry. The aforementioned result implies that a 40% reduction in the level of salt added to a chilli con carne ready-meal is possible without consumers noticing a difference in the taste of the meal. This could potentially be done in increments of approximately 10%, up to a maximum of 40%, to ensure that the consumers salt taste threshold is reduced over time. Based on the commercial ready-meal portion size of 500g used in this study, a reduction in salt levels of this magnitude i.e. 40%, from the chilli con carne ready-meal would result in the removal of 2g of salt from a consumer’s daily diet, equivalent to removing 50% of Ireland’s recommended dietary allowance (RDA) of salt. Removal of 0.5% salt from this particular ready-meal seems to be the cut off point for salt reduction, as panellists were able to identify the odd/different sample during triangle tests at this concentration.

<table>
<thead>
<tr>
<th>Ready-Meal Salt Concentration</th>
<th>Significant Difference to Regular Salt Ready-Meal¹</th>
<th>Paired Comparison Test</th>
<th>Triangle Test</th>
<th>Preference Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4%</td>
<td></td>
<td>0.003</td>
<td>0.004</td>
<td>0.144</td>
</tr>
<tr>
<td>0.5%</td>
<td></td>
<td>0.144</td>
<td>0.001</td>
<td>0.715</td>
</tr>
<tr>
<td>0.6%</td>
<td></td>
<td>0.273</td>
<td>0.092</td>
<td>0.715</td>
</tr>
<tr>
<td>0.8%</td>
<td></td>
<td>0.144</td>
<td>0.339</td>
<td>0.465</td>
</tr>
<tr>
<td>1.25%</td>
<td></td>
<td>0.000</td>
<td>0.000</td>
<td>0.715</td>
</tr>
</tbody>
</table>

¹Results of Compusense® five statistical analyses for comparison of regular salt chilli con carne ready-meals with reduced salt chilli con carne ready-meals with salt added at levels from 0-1.1%.

Results from the preference tests (Table 4.4) indicate that panellists expressed no significant preference (p>0.05) for the regular salt ready-meals (1.0% salt) over any of the varying salt ready-meals (0.4, 0.5, 0.6, 0.8, 1.25 & 1.5% salt). This result is surprising given the fact the panellists were able to determine differences between the regular salt meal and several of the varying salt ready-meals, particularly those at the
higher salt concentrations, during paired comparison and triangle tests. It is believed that high salt consumption is a consequence of habits learned during development (Bertino et al., 1982; Malherbe et al., 2003). Therefore, persons that continually consume a high salt diet will ultimately require a higher sodium concentration for a specific product to be acceptable (Malherbe et al., 2003), and will in time become desensitised to the salt taste. However, results from the present study appear to be in disagreement with this view-point as panellists were able to detect differences between both the reduced salt (0.4 and 0.5%) and high salt (1.25 and 1.5%) meals when compared to the regular salt samples (1.0% salt) during earlier difference tests. This highlights that panellists were sensitive to both low and high salt levels in the ready-meals. And yet despite this sensitivity, panellists expressed no significant preference for the regular salt ready-meals (1.0% salt) over any of the varying salt ready-meals. Ainsworth et al. (1993) reported similar results when salt levels ranging from 0-0.68% were added to chilli con carne ready-meals and salt levels ranging from 0.17-0.85% were added to ratatouille ready-meals; no significant difference in panellist’s acceptability scores was observed among the samples.

4.4.1.3 Lasagne
P-value results for these sensory tests are presented in Table 4.5. In paired comparison tests panellists detected a significant difference in salt taste between the regular salt meal and the reduced salt meals with final concentrations of 0.55% and 0.65% salt (p<0.005). At salt concentrations of 0.75% and 0.85% panellists reported no significant difference (p>0.05) between the regular salt lasagne ready-meal and either of these two reduced salt meals indicating that there was no difference between these meals in terms of salty taste. Similarly triangle tests indicated a significant difference (p<0.005) between the regular salt ready-meal and reduced salt meals with 0.55% and 0.65% salt. Un-expectedly panellists were also able to detect a significant difference between the 0.85% reduced salt meal and the regular salt ready-meal (p<0.005). This result highlights the importance of combining the attribute specific paired comparison test with the triangle test, as although panellists could not differentiate between the regular salt meal and the 0.85% reduced salt meal with regards to salty taste during the paired comparison test, they were able to detect a significant difference in terms of overall taste during the triangle test. Therefore,
despite salty taste being unaffected in the reduced salt meal the decrease in salt content in the meal may have affected other sensory properties of the meal such as flavour intensity or texture for example. No significant difference (p>0.05) was reported between the 0.75% reduced salt meal and the regular salt ready-meal in triangle tests, indicating that panellists were unable to distinguish an overall difference between these two meals. Discounting the apparent anomaly at 0.85% NaCl, this result combined with results from the paired comparison test would appear to indicate that the maximum amount of salt to be removed from a frozen lasagne ready-meal without panellists noticing a difference in taste is 0.3% salt, an overall salt reduction of 29%. Therefore, gradual salt reductions of approximately 10% could be slowly made to this meal until an overall salt reduction of 29% is achieved. Preference tests comparing each of the reduced salt meals with the regular salt ready-meal found panellists expressed no significant preference (p>0.05) between the regular salt and reduced salt meals with 0.55%, 0.75% and 0.85% salt concentrations. Panellists did however, show a significant preference (p<0.005) for the regular salt lasagne over the 0.65% reduced salt meal, with 23 out of 30 panellists preferring the regular salt meal over this particular reduced salt meal. A salt reduction of this scale i.e. approximately 40%, from the original recipe at once may have caused an off-balanced flavour within the meal which the panellists could detect. Smaller reductions of approximately 10% result in the sensory attributes of the food appearing unchanged to the consumer as their salt appetite adjusts to the decreased salt level over time (Bertino et al., 1982).

Table 4.5: Probability Levels Associated with Sensory Analyses of Lasagne Ready-Meals with Salt Levels of 0.55-0.85% (w/v)

<table>
<thead>
<tr>
<th>Ready-Meal Salt Concentration</th>
<th>Paired Comparison Test</th>
<th>Triangle Test</th>
<th>Preference Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.55%</td>
<td>0.003</td>
<td>0.004</td>
<td>0.273</td>
</tr>
<tr>
<td>0.65%</td>
<td>0.000</td>
<td>0.000</td>
<td>0.003</td>
</tr>
<tr>
<td>0.75%</td>
<td>0.273</td>
<td>0.092</td>
<td>0.715</td>
</tr>
<tr>
<td>0.85%</td>
<td>0.465</td>
<td>0.001</td>
<td>0.273</td>
</tr>
</tbody>
</table>

1Results of Compusense® five statistical analyses for comparison of regular salt lasagne ready-meals with reduced salt lasagne ready-meals with salt added at levels from 0-0.3%.
It must be noted that the level of salt reduction achievable using this current gradual salt reduction strategy will vary, not only between different foods but also among the same types of food, and will be very much product and process specific. The current study highlighted this fact showing that gradual salt reductions ranging from 29% to 40% could be achieved in the different ready-meals. This again highlights that the level of salt reduction achievable via a gradual salt reduction strategy is very much related to the product in question.

4.4.2 Effect of the Addition of Salt Substitutes/Flavour Enhancers on the Sensory Properties of Reduced Salt Frozen Ready-Meals

The second salt reduction approach which could potentially be employed by the food industry is the use of salt substitutes and flavour enhancers. This approach involves immediately removing the desired amount of salt from the original product and masking the effect on the sensory properties with salt substitutes or flavour enhancers. The different salt substitutes and flavour enhancers used during in the present study are listed in Table 4.2. Potassium chloride (KCl) is one of the most commonly used salt substitutes within the food industry today. However, the bitter taste often associated with the use of KCl in reduced salt/sodium foods has limited its industrial use. AlsoSalt® is a mixture of potassium chloride and the amino acid L-lysine monohydrochloride. This salt substitute is typical of the many salt substitutes used today as it combines potassium chloride with a ‘bitter blocker’ i.e. a substance which masks the bitter taste associated with potassium chloride. According to the manufacturers of AlsoSalt® (AlsoSalt, Maple Valley, Washington, USA), L-lysine has a unique salty flavour of its own which when combined with potassium chloride masks the associated bitter taste. Yeast extracts are commonly used in food as salt substitutes and/or flavour enhancers as they impart bouillon-like, clean tastes thus giving them the ability to enhance existing food ingredients such as meat and spices (Brandsma, 2006; Desmond, 2006). According to the manufacturers Provesta® 029, a combination of autolyzed yeast and potassium chloride, is purported to provide saltiness with less bitterness than KCl alone (ABF Ingredients, 2006). Provesta® 001 is a whole cell Torula yeast purported to contribute a clean savoury flavour, enhancing meat flavours, increasing the umami effect and because of its’ mild flavour is an excellent carrier for spices and seasoning mixes (ABF Ingredients, 2006).
Provesta® 512 is a low sodium autolyzed yeast extract containing a high level of the naturally occurring 5’-nucleotides IMP and GMP (disodium inosinate and disodium guanylate), which manufacturers claim amplifies flavours and contributes a umami effect (ABF Ingredients, 2006). Provesta® 027 is described as a unique, low sodium yeast autolysate designed to increase the overall flavour of poultry, pork and other meat based food formulations with a mild flavour profile. Finally, Provesta® 000 is a whole cell Torula yeast extract, which provides an increase in overall flavour, salt perception and umami effect (ABF Ingredients, 2006).

4.4.2.1 Chicken Curry

Salt Substitute 1 – Potassium Chloride (KCl)
KCl was added as a salt substitute to the lowest salt (0.2% salt) model ready-meal at a level of 0.4%, a replacement of 66.6% of the salt content originally present in the regular salt chicken curry meal (0.6%). From Table 4.6 it can be seen that in paired comparison tests panellists found no significant difference (p>0.05) between the regular salt meal and the reduced salt meal containing 0.4% KCl. No significant difference (p>0.05) was detected between these two meals during the triangle test with 8 out of 20 panellists correctly identifying the odd sample. These results indicate that panellists were unable to tell the difference between the regular salt ready-meal and the reduced salt ready-meal with 0.4% KCl. In addition, panellists did not report a bitter taste or aftertaste normally associated with the use of potassium chloride.
Table 4.6: Probability Levels Associated with Sensory Analyses of Chicken Curry Ready-Meals with 0.4% Added Salt Substitutes

<table>
<thead>
<tr>
<th>Salt Substitutes</th>
<th>Significant Difference to Regular Salt Ready-Meals&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Paired Comparison Test</th>
<th>Triangle Test</th>
<th>Preference Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>KCl</td>
<td></td>
<td>0.715</td>
<td>0.339</td>
<td>0.715</td>
</tr>
<tr>
<td>AlsoSalt®</td>
<td></td>
<td>0.715</td>
<td>0.946</td>
<td>0.465</td>
</tr>
<tr>
<td>Provesta® 000</td>
<td></td>
<td>0.715</td>
<td>0.004</td>
<td>0.011</td>
</tr>
<tr>
<td>Provesta® 027</td>
<td></td>
<td>0.011</td>
<td>0.000</td>
<td>0.465</td>
</tr>
<tr>
<td>Provesta® 029</td>
<td></td>
<td>0.001</td>
<td>0.004</td>
<td>0.715</td>
</tr>
</tbody>
</table>

<sup>1</sup>Results of Compusense® five statistical analyses for comparison of regular salt chicken curry ready-meals with reduced salt chicken curry ready-meals with salt substitutes added at a level of 0.4%.

Panellists did not express a significant preference between the regular salt ready-meal and reduced salt KCl samples (p>0.05) with 14 out of 30 panellists preferring the reduced salt meal to the regular salt meal. When panellists were presented with samples of all salt substitutes used and a sample of the regular salt meal and asked to rank them in terms of preference, the reduced salt meal containing KCl was ranked second (Figure 4.1). The highest ranked meal was the regular salt sample (0.6% NaCl), however, no significant difference (p>0.05) was observed between the regular salt sample and the reduced salt KCl sample.
Figure 4.1: Rank Totals (Based on Sum of Rank) for Ranking Preference Test of Regular Salt Chicken Curry (0.6%) and All Salt Substitutes Incorporated at a Concentration of 0.4% into Reduced Salt (0.2%) Chicken Curry Ready-Meals (n=6; p<0.05)

Salt Substitute 2 - AlsoSalt®

AlsoSalt® was added to the chicken curry ready-meals in a similar manner to potassium chloride. Paired comparison tests revealed that the incorporation of AlsoSalt® into the reduced salt ready-meal resulted in panelists detecting no significant difference in salty taste between it and the regular salt sample (p>0.05; Table 4.6). In addition, a significant difference (p>0.05) was not detected between the AlsoSalt® samples and regular salt samples in triangle tests, with only 6 panelists from 20 correctly identifying the odd sample. These results indicate that panelists were unable to distinguish between the regular salt ready-meal and the reduced salt ready-meal containing the AlsoSalt®. In preference tests, 17 out of 30 panelists preferred the reduced salt meal containing AlsoSalt® to the regular salt ready-meal, with no significant difference (p>0.05) being found between the two samples in terms of preference. AlsoSalt® was ranked 4th during the ranking test where all 5 salt substitutes and the control were presented (Figure 4.1). However, no significant difference was found between the AlsoSalt® sample and any of the other 5 samples (p>0.05).

1 Different letters indicate significantly different samples, calculated using Friedman’s Analysis of Rank.
Salt Substitute 3 - Provesta® 029

In paired comparison tests, panellists found a significant difference (p<0.05; Table 4.6) in taste between the regular salt meal and the reduced salt meal containing Provesta® 029. A significant difference (p<0.005) was again detected following triangle testing for this salt substitute with 13 out of 20 panellists correctly identifying the odd sample. Taken together these results indicate that panelists were easily able to distinguish between the regular salt ready-meal and the reduced salt ready-meal containing Provesta® 029. Despite this, a significant difference (p>0.05) was not found during preference testing between the regular salt ready-meal and the Provesta® 029 containing ready-meal. In the ranking preference test (Figure 4.1) where all salt substitutes were presented, panelists ranked Provesta® 029 as the 3rd favourite sample, after the control and KCl. However, a significant difference was not detected between this salt substitute and any of the other samples during this ranking preference test (p>0.05).

Salt Substitutes 4 - Provesta® 027

Results from paired comparison tests revealed that panelists found a significant difference (p<0.05; Table 4.6) in taste between the regular salt meal and the reduced salt meals containing Provesta® 027. When these meals were compared in a triangle test a significant difference (p<0.005) was again detected by panelists with 15 out of 20 panelists correctly identifying the odd/different sample. These results indicate that sensory panelists were able to distinguish between the regular salt ready-meal and the reduced salt ready-meals containing Provesta® 027. In spite of this, a significant difference (p>0.05) was not reported in the preference tests between the regular salt meal and Provesta® 027. In a ranking preference test (Figure 4.1) where all salt substitutes were presented, panelists ranked Provesta® 027 as 5th, indicating it was the 2nd least favourite sample. A significant difference was not detected between this sample and any of the other samples during this preference ranking test (p>0.05).

Salt Substitutes 5 - Provesta® 000

The final salt substitute incorporated into the reduced salt meal was Provesta® 000. No significant difference was found between the Provesta® 000 ready-meal and the
regular salt ready-meal in paired comparison tests \((p>0.05; \text{Table 4.6})\) indicating that panellists were unable to detect a difference between the meals in terms of salt taste. However, a significant difference was detected by panellists in triangle tests \((p<0.005)\). In fact, panellists commented that they found the meal containing Provesta® 000 to have a slightly ‘bland’ curry taste and that it was ‘less spicy’ in comparison to the regular salt ready-meal. These comments were reflected in the preference test results with only 8 out of 30 panellists \((p<0.05)\) preferring the reduced salt meal containing Provesta® 000 to the regular salt meal. This meal was ranked 6th during the preference ranking test (Figure 4.1) indicating that it was the least liked sample of all the salt substitutes and was again found to be significantly different \((p<0.05)\) to the regular salt ready-meal.

\[ \text{Table 4.6} \]

\begin{center}
\begin{tabular}{ |c|c|c| }
\hline
Meal & Panellist Preference & Significance \(p\) \\
\hline
Regular Salt Meal & 22 & 0.05 \\
Provesta® 000 Meal & 13 & 0.05 \\
\hline
\end{tabular}
\end{center}

\textbf{4.4.2.2 Chilli Con Carne}

Salt Substitute 1 - Potassium Chloride (KCl)

Potassium chloride (KCl) is one of the most widely used salt substitutes within the food industry today; however, at high levels KCl can impart bitter/metallic notes to food, thus compromising their sensory acceptability. In the present study, 60% of the overall salt (NaCl) content from a chilli con carne ready-meal was replaced with KCl. Results presented in Table 4.7 illustrate that panellists detected no significant difference in salty taste between the regular salt ready-meal and the reduced salt meal containing 0.5% KCl \((p>0.05)\) in attribute specific paired comparison tests. However, when both these meals were compared during triangle tests panellists found a significant difference \((p<0.005)\) between the meals, with the majority of panellists (17 out of 20) accurately identifying the odd/different sample. Therefore, although the salty taste of the ready-meal was not affected by the substitution of KCl for NaCl, the overall flavour and taste of the product was affected. A spicy, amino acid rich and texturized foodstuff, such as chilli con carne, is generally regarded to be not as sensitive to salt reduction and replacement by KCl, as other milder and less seasoned foods, due to the naturally high level of umami, kokumi and amino acid compounds (Dunkel et al., 2007) found in the meal. However, results from the present study are in disagreement with this viewpoint, as the majority of panellists were able to distinguish between the reduced salt KCl containing ready-meal and the commercial
chilli con carne during triangle tests. Results from the current study whereby a sensory difference was seen during triangle tests, is something which food manufacturers will want to avoid, as regular consumers of the product could potentially perceive the overall taste difference and as a result choose not to repurchase.

Table 4.7: Probability Levels Associated with Sensory Analyses of Chilli Con Carne Ready-Meals with 0.5% Added Salt Substitutes

<table>
<thead>
<tr>
<th>Salt Substitutes</th>
<th>Significant Difference to Regular Salt Ready-Meals</th>
<th>Paired Comparison Test</th>
<th>Triangle Test</th>
<th>Preference Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>KCl</td>
<td></td>
<td>0.465</td>
<td>0.000</td>
<td>0.773</td>
</tr>
<tr>
<td>AlsoSalt®</td>
<td></td>
<td>0.197</td>
<td>0.607</td>
<td>0.020</td>
</tr>
<tr>
<td>Provesta® 029</td>
<td></td>
<td>0.011</td>
<td>0.001</td>
<td>0.715</td>
</tr>
<tr>
<td>Provesta® 001</td>
<td></td>
<td>0.003</td>
<td>0.000</td>
<td>0.715</td>
</tr>
<tr>
<td>Provesta® 512</td>
<td></td>
<td>0.439</td>
<td>0.178</td>
<td>0.197</td>
</tr>
</tbody>
</table>

1Results of Compusense® five statistical analyses for comparison of regular salt chilli con carne ready-meals with reduced salt chilli con carne ready-meals with salt substitutes added at a level of 0.5%.

When panellists were presented with the two samples and asked to choose which sample they preferred, they expressed no significant preference for one meal over the other (p>0.05). Furthermore, when panellists were presented with samples of chilli con carne containing all the various salt substitutes used during this study and a sample of the regular salt meal, and asked to rank them in terms of their preference, no significant difference (Figure 4.2; p>0.05) was found between the low-salt KCl sample and any of the 5 other samples. Gelabert et al., (2003) found substitution levels of 40% KCl in place of salt in fermented sausages resulted in acceptable flavour properties. Sanceda et al., (2003) found partial substitution of salt with KCl up to a ratio of 75:25 acceptable in fish sauce; however, above these level panellists noted unacceptable levels of bitterness in the product. Phelps et al., (2006) found 50:50 sodium chloride/potassium chloride blend’s a common practical limit. Despite the apparent limitations of its usage in different foods in terms of health the replacement of salt with potassium chloride results in an added health benefit as a
potassium rich diet is known to further reduce blood pressure (Geleijnse et al., 2003; Dötsch et al., 2009). Despite a sensory difference being observed by panellists during earlier sensory testing panellists’ preference for a chilli con carne ready-meal was not effected by the change in salt formulation and preference for the meal was found to be comparable with the regular salt meal (p>0.05). The umami nature of chilli con carne as well as the presence of ‘kokumi’ compounds found in the beans (Dunkel et al., 2007) present in these particular ready-meals, may potentially be responsible for the panellists showing no preference for one meal over the other during preference tests, as both taste characteristics are known to enhance the flavours of dishes such as Mexican chillies (Dunkel et al., 2007). It must also be noted at this time that panellists did not comment on any bitter or metallic taste or aftertaste that is usually associated with the inclusion of potassium chloride. The ‘hot’ notes imparted by the chilli and the presence of a significant level of spices in the meal may have masked the bitter taste associated with the inclusion of KCl.

Salt Substitute 2 - AlsoSalt®

Results from sensory analyses, whereby 60% of the salt was replaced with a commercial mixture of KCl and L-lysine, found no significant difference (p>0.05) in salty taste following paired comparison tests between the regular salt meal and the reduced salt meal containing this salt substitute (Table 4.7). No significant difference (p>0.05) was detected between the regular salt samples and the reduced salt AlsoSalt® samples during triangle tests, where only 4 panellists correctly identified the odd/different sample. These results indicate that panellists were unable to differentiate between the regular salt chilli con carne ready-meal and the reduced salt meal containing a mixture of KCI and L-lysine in terms of both overall difference and salt taste, a result which food manufacturers strive to achieve when incorporating a salt substitute into a reduced salt food. Guerrero et al., (1995) reported that a mixture of the amino acids lysine and arginine and an ammonium salt not only enhanced the salty taste of some foods and beverages but also enhanced other flavours present.
Regardless of the fact that panellists were unable to distinguish between the two meals, they expressed a significant preference for the regular salt ready-meal over the reduced salt meal containing AlsoSalt® (p<0.05), with only 3 panellists preferring the reduced salt AlsoSalt® meal. It is again important to note that although this particular salt substitute is a KCl-based salt replacer, panellists did not detect any specific bitter or metallic flavour notes in the meals and therefore, this result suggests that the incorporation of 0.5% of AlsoSalt®, a commercial mixture of KCl and L-lysine, had an adverse effect on some of the other sensory properties of the meal. Finally, when meals containing all 5 salt substitutes and the control were ranked, no significant preference was shown for any one sample over the other (p>0.05; Figure 4.2).

1 Different letters indicate significantly different samples, calculated using Friedman’s Analysis of Rank.
Salt Substitute 3 - Provesta® 001
In paired comparison tests, panellists noted a significant difference (p<0.05; Table 4.7) in salty taste between the regular salt ready-meals and the reduced salt meals containing Provesta® 001, a whole cell yeast, with a total of 23 out of 30 panellists correctly identifying the regular salt meal as being the saltier meal. A significant difference (p<0.005) was again detected by panellists during the triangle test with the majority of panellists correctly identifying the odd/different sample during testing. These results indicate that panellists were able to distinguish between the regular salt ready-meal and the reduced salt ready-meals containing Provesta® 001 in terms of salty taste and overall taste. Despite this, no significant preference (p>0.05, Table 4.7) was shown for either ready-meal during the basic preference test. During the final ranking preference test (Figure 4.2) no significant difference was observed among the samples (p>0.05).

Salt Substitute 4 - Provesta® 029
Results from the paired comparison test revealed that panellists found the regular salt meal to have a significantly saltier taste (P<0.05; Table 4.7) than the reduced salt meals containing Provesta® 029, a KCl/autolysed yeast salt substitute. Results from the triangle tests showed panellists perceived a significant difference (P<0.005) between the samples, with nearly all panellists correctly identifying the odd/different sample from the 3 presented. These results combined indicate that panellists were able to discriminate between the regular salt ready-meal and the reduced salt ready-meals containing the Provesta® 029. Despite this, no significant preference (p>0.05, Table 4.7) was shown for the regular salt ready-meal over the reduced salt meals containing Provesta® 029 during a basic preference test. During the final ranking preference test (Figure 4.2) no significant preference was observed among the samples (p>0.05). It is once again important to note that although the present salt substitute contained KCl, panellists did not comment on any bitter or metallic flavours in the meals.
Salt Substitute 5 - Provesta® 512

The third yeast based flavour enhancer incorporated into the reduced salt chilli con carne ready-meal was Provesta® 512, a nucleotide yeast extract, a product naturally high in IMP and GMP, both of which are often associated with the characteristic taste of umami (Halpern, 2000; Kilcast and den Ridder, 2007). No significant difference (p>0.05, Table 4.7) in salty taste was found between the regular salt and the reduced salt meals containing Provesta® 512 in paired comparison tests, and similarly, no significant difference was found between these two meals during the triangle test (p>0.05). In addition, panellists expressed no significant preference (p>0.05, Table 4.7) for either the regular salt ready-meal or the Provesta® 512 containing meals in the basic preference test. During the ranking preference test (Figure 4.2) panellists showed no significant preference for any one of the six samples presented (p>0.05), however, the Provesta® 512 sample received scores almost identical to that of the regular salt sample. This blend of 40% salt and 50% nucleotide yeast extract proved to be the most successful of all the salt substitutes trialled, as not only were panellists preference for this meal comparable with that of the regular salt meal, they were also unable to distinguish a difference between the meals during difference tests.

4.4.2.3 Lasagne

Salt Substitute 1 – Potassium Chloride (KCl)

Sensory tests indicated that panellists were unable to detect a difference in salty taste and overall taste between the regular salt meal and the reduced salt meal containing KCl in the paired comparison and triangle tests (p>0.05; Table 4.8). It is important to note that panellists did not comment on any bitter/metallic taste or aftertaste that is usually associated with the inclusion of potassium chloride in foods. In preference tests 19 out of 30 panellists preferred the reduced salt KCl meal to the regular salt ready-meal; however, this was not a significant preference (p>0.05). In a ranking preference test where all salt substitute samples along with the regular salt sample were presented to panellists, the reduced salt meal containing KCl was ranked second favourite (Figure 4.3), however, it must be noted that there was no significant difference/preference between any of the samples (p>0.05).
Table 4.8: Probability Levels Associated with Sensory Analyses of Lasagne Ready-Meals with 0.5% Added Salt Substitutes

<table>
<thead>
<tr>
<th>Salt Substitutes</th>
<th>Significant Difference to Regular Salt Ready-Meals¹</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Paired Comparison Test</td>
<td>Triangle Test</td>
<td>Preference Test</td>
</tr>
<tr>
<td>KCl</td>
<td>0.715</td>
<td>0.092</td>
<td>0.144</td>
</tr>
<tr>
<td>AlsoSalt®</td>
<td>0.465</td>
<td>0.004</td>
<td>0.011</td>
</tr>
<tr>
<td>Provesta® 512</td>
<td>0.000</td>
<td>0.000</td>
<td>0.068</td>
</tr>
</tbody>
</table>

¹Results of Compusense® five statistical analyses for comparison of regular salt lasagne ready-meals with reduced salt lasagne ready-meals with salt substitutes added at a level of 0.5%.

Salt Substitute 2 - AlsoSalt®

Similar to the use of KCl alone in a lasagne ready-meal, panellists did not report any bitter taste or aftertaste in the reduced salt AlsoSalt® containing meal in this study. Paired comparison tests indicated that there was no significant difference (Table 4.8, p>0.05) between the regular salt ready-meal and this reduced salt ready-meal in terms of saltiness, however, in triangle tests a significant difference (p<0.005) between these meals was observed. While panellists could differentiate between the regular salt lasagne ready-meal and the reduced salt meal containing AlsoSalt®, they could not distinguish between these two meals on the basis of salt taste. Therefore, while the loss in salty taste could be replaced through the inclusion of AlsoSalt®, the ability to enhance and intensify other flavours present in a food resulting from salt inclusion could not be replaced. Preference tests indicated that panellists significantly preferred (p<0.05; Table 4.8) the reduced salt AlsoSalt® meal over the regular salt ready-meal. In fact this meal was rated as the most preferred meal (Figure 4.3) during the ranking preference test, however, this preference was not statistically significant (p>0.05).
Figure 4.3: Rank Totals (Based on Sum of Rank) For Ranking Preference Test of Regular Salt Lasagne (1.05%) and All Salt Substitutes Incorporated at a Concentration of 0.5% into Reduced Salt (0.55%) Lasagne Ready-Meals (n=4; p>0.05)\(^1\)

![Bar chart showing rank totals for different salt substitutes.](image)

\(^1\) Different letters indicate significantly different samples, calculated using Friedman’s Analysis of Rank.

**Salt Substitute 3 – Provesta® 512**

Table 4.8 illustrates that in paired comparison tests panellists detected a significant difference (p<0.005) in terms of salty taste between the regular salt lasagne ready-meal and the reduced salt meal containing Provesta® 512. Panellists also detected a significant difference (p<0.005) between these two meals in triangle tests. Despite panellists ability to differentiate between these two meals in terms of saltiness and overall taste they showed no significant preference (p>0.05; Table 4.8) for either of the meals during the basic preference test and ranked it as third favourite (Figure 4.3) above the regular salt ready-meal during the ranking preference test (p>0.05).

Results from this part of the study highlight the importance of sensory analyses in the re-formulation of reduced salted products. Results show that altering formulations by lowering the salt content and by the introduction of new ingredients will not only affect different products in different ways but will also affect similar products in different ways. Manufacturers who wish to adopt this approach need to
invest time in the search for the right salt substitute for their product, a search which may prove tedious due to the large number of salt substitutes and flavour enhancers currently on the market. Time also needs to be invested into conducting the required sensory analyses to evaluate the suitability of each salt substitute to the specific product formulation. Despite this time requirement, if a suitable salt substitute can be found for a product, the investment in time will be rewarded by the continued support for the product among its consumers. Furthermore, by combining both of these popular salt reduction strategies discussed in this chapter, manufacturers will not only be able to achieve a gradual level of salt reduction but also will simultaneously have the time to invest in the search for a suitable salt substitute/flavour enhancer.

4.4.3 Consumer Acceptability of Reformulated Reduced Salt Lasagne
Lasagne ready-meals were selected for inclusion in a large scale consumer acceptability trial to determine consumer response to the reduced salt ready-meals in comparison to its regular salt commercial counterpart. Based on previous results from the lasagne salt substitutes study (Table 4.8) it was decided to incorporate potassium chloride at a level of 0.5% into the lowest salt lasagne ready-meal (0.55% salt) for further acceptability testing as it proved the most promising of the three salt substitutes tested. Results from the consumer acceptability trial are shown in Figure 4.4. This Figure illustrates that 78% of consumers perceived the two samples to be different ready-meals, while 22% perceived them to be the same ready-meal (p<0.005). Both lasagne samples were considered to be acceptable with sensory scores placing both samples between ‘like very much’ = 8 and ‘like moderately’ = 7. The reduced salt meal containing KCl was favoured slightly above the regular salt commercial meal; however, this was not a significant difference (p>0.05).
Figure 4.4: Paired Comparison and Acceptability Scores from a Consumer Acceptability Trial (n=175) Comparing Regular Salt Lasagne Ready-Meals with Reduced Salt KCl Ready-Meals

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Percentage of consumers who perceived sample to be the same or different. * Mean consumer acceptability score, where 9=like extremely, 8=like very much, 7=like moderately, 6=like slightly, 5=neither like nor dislike, 4=dislike slightly, 3=dislike moderately, 2=dislike very much, 1=dislike extremely.

In the present study sensory analyses was carried out in the order of paired comparison test, triangle test and preference test as stated in the materials and methods section. However, by conducting the preference test last panellists may have been introduced to some degree of bias arising from the questions asked of them during the difference tests. In hindsight it would have been preferable to have conducted sensory analyses in the following order: preference test, triangle test and paired comparison test. Therefore, this should be taken into account when interpreting this data.

4.5 Conclusions
The study showed that salt levels in chicken curry ready-meals could be gradually reduced by approximately 33%, by approximately 50% in chilli con carne ready-meals and approximately 29% in lasagne ready-meals. Therefore, the maximum amount of salt which could be removed from the ready-meals via a gradual salt reduction strategy equated to a salt reduction of 0.2% in chicken curry ready-meals, a 0.5% salt reduction in chilli con carne ready-meals and a reduction of 0.3% salt in
lasagne ready-meals. Sensory analyses including triangle, paired comparison and preference tests revealed that the incorporation of the commercial salt substitute, AlsoSalt®, an amino acid and potassium chloride blend, into chicken curry ready-meals allowed salt levels to be reduced to a final concentration of 0.2%, an overall salt reduction of 66%, without panellists detecting a noticeable difference in taste. Salt reductions of 60% were achieved in chilli con carne ready-meals via the addition of Provesta® 512, a nucleotide yeast extract. Finally, the addition of the popular salt substitute potassium chloride (KCl) into lasagne ready-meals resulted in salt levels being reduced to a final concentration of 0.55% salt, an overall salt reduction of 48%. Concerns over the use of KCl based salt substitutes imparting bitter notes at the levels used in this study for all three ready-meals were not justified.
Chapter 5
5. Impact of Salt Reduction on the Instrumental and Sensory Flavour Profile of Reduced Salt Chilled Ready-Meals

5.1 Abstract

The flavour of 3 commercial regular salt ready-meals, cottage pie (0.80% NaCl), chicken supreme (0.55% NaCl) and vegetable soup (0.93% NaCl), and their reformulated reduced salt equivalents (0.35%, 0.33% and 0.45% NaCl, respectively), were profiled using flavour profile analysis and solid-phase microextraction (SPME) coupled with gas chromatography mass spectrometry (GC-MS) instrumental analysis. Reduction of salt in the cottage pie had a significant impact on the attributes “uneven surface colour”, “oily flavour”, “oily surface shine” and “translucent appearance”. Sensory data for chicken supreme revealed that the attributes “sweet flavour” and “uneven surface colour” were significantly higher (p<0.05) in the reduced salt ready-meal. While salt reduction in the vegetable soup had a significant effect (p<0.05) on the sensory attributes “green colour”, “sweet flavour” and “pepper flavour”. SPME-GCMS analysis revealed a higher proportion of terpenes and aldehydes present in the headspace of both the reduced salt cottage pie and reduced salt chicken supreme ready-meals. In comparison, SPME-GCMS analysis revealed a ‘salting-out’ effect in the regular salt soup with significantly higher concentrations of terpenes and thioethers identified in comparison to its reduced salt counterpart. Partial least squares regression (PLSR) of the ready-meal data identified several significant positive relationships between the identified volatile compounds and several sensory attributes associated with the regular salt ready-meals. Information of this nature can potentially be used in a reformulation strategy based on monitoring changes in volatile profiles arising from a reduction in salt. This would allow manufacturers’ to select specific salt substitutes which are compatible with the volatile profile of the original salted product.

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1 The work described in this chapter has been published in Food Research International (Mitchell, M., Brunton, N.P., and Wilkinson, M.G. (2011). Impact of Salt Reduction on the Instrumental and Sensory Flavor Profile of Vegetable Soup. Food Research International, 44, 1036-1043).
5.2 Introduction
The rationales behind consumer food purchasing choices are many and varied; however, undoubtedly one of the most important motives in terms of repurchasing is whether a food product tastes good. Concurrent with the demand today for food products that are tasty and convenient, is the additional requirement that these products contain reduced levels of sugar, fat and salt (sodium chloride). Consequently, there is pressure on manufacturers to achieve these goals without impacting on the original taste and flavour of the product. In addition, with the evidence relating high sodium consumption to high blood pressure steadily increasing (Intersalt Cooperative Research Group, 1988; Law, 1997; FSAI Scientific Committee, 2005), health organizations worldwide have called for a reduction in the average sodium intake of the general population, through a reduction of the sodium chloride content in processed foods (World Health Organisation, 2003; Scientific Advisory Committee on Nutrition, 2003; FSAI Scientific Committee, 2005). Processed foods, including soups, ready-meals and comminuted meat products are a leading contributor to salt intake worldwide (Durack et al., 2008). However, the salt in these foods performs a number of important technological functions, ranging from preservation to increased processibility. One of the most important roles of salt lies in its ability to impart distinctive taste properties, including the enhancement and/or modification of the flavour and tastes of other ingredients within a food (Hutton, 2002; Durack et al., 2008). Therefore, any changes made to the formulation of a product e.g. by reducing salt, will thus modify the perception of flavour by changing the nature of the interactions involved (Guichard, 2002), and could ultimately result in a product whose taste and flavour is inferior to that of the original salted product.

Flavor perception is a dynamic process and one which must engage the consumer, in addition to the chemistry and physics of the food (Piggott, 2000). It is an essential element of the quality and acceptability of foods; however, it can be an extremely difficult element to control (Heng et al., 2004). New food ingredients, processing and storage conditions, can lead to changes in the overall flavour perception of a product as a result of reduced aroma volatile intensity or through the production of off-flavour compounds (Heng et al., 2004). Physiochemical properties of aroma compounds and their interactions with other food components such as proteins, fats and carbohydrates, can affect flavour release and perception (Chung et
al., 2003; Voilley and Etiévant, 2006; Ventanas et al., 2010). Typically, the presence of proteins, fats and carbohydrates decrease the volatility of aroma compounds, whilst the inclusion of salt increases volatility (Guichard, 2002, Ventanas et al., 2010). Only a small number of the volatiles present in a food actually contribute to a given aroma or flavour. The role of these “odour-active” compounds in a given food depends upon their concentration and on their individual odour threshold (Schieberle and Grosch, 1987; Pérez-Juan et al., 2007; Ventanas et al., 2010). Perception of flavour and aroma volatiles is further influenced by their solubility within a food which can subsequently be affected by the level of salt present. The addition of salt to foodstuffs results in reduced water activity (a<sub>w</sub>) levels as the salt in solution acts to “tie-up” some of the free available water thus, increasing the concentration of flavour volatiles in the free residual water (Hutton, 2002; Flores et al., 2007). The affinity of water for the salts ions is considerably stronger than for the flavour volatiles due to the formation of strong ion-dipole interactions (Rabe et al., 2003). This phenomenon known as the “salting-out” effect results in increased flavour release from foods due to the decreased availability of water molecules for the solubilisation of flavour compounds (Rabe et al., 2003; Flores et al., 2007).

Many food manufacturers now use complex statistical analyses in order to achieve the best product formulation in relation to sensory acceptability, shelf life, nutritional demands and physiochemical stability (Granato et al., 2011). Generalized procrustes analysis (GPA) is a technique in which data generated by each panel member is analyzed separately, correcting for individual differences in the use of the line-scale and in the interpretation of the sensory attributes (Grower, 1975; Byrne et al., 2001). Although this process of analysis is commonly associated with the free choice profiling (FCP) method, it is practical in the analysis of conventional profiling data as despite extensive training individual differences between panellists can still exist (Dijksterhuis, 1995). GPA generates a consensus plot that matches the configuration of the data sets by centering, rotating and adjusting scales of each data set (Chung et al., 2003). Thus, the three major elements, samples, panellists and sensory attributes can be examined and contrasted using a single encompassing analysis (de Jong et al., 1997). Partial least squares regression (PLSR) is frequently used to understand the relationships between instrumental (X) and sensory (Y) data sets by predicting one data set from the other (Martens and Martens, 2001). PLSR
provides solutions to both X and Y variables and simultaneously investigates the relationship between instrumental volatile compounds and sensory attributes.

Despite the downward pressure on salt levels there is still very little published information on the exact impact that salt reductions have on the sensory characteristics and the volatile composition of complex food systems such as ready-meals. Information of this nature could potentially be used in a reformulation strategy based on changes in volatile profiles arising from a reduction in salt. Therefore, in the present study, we investigated the flavour profile of three reduced salt ready-meals, cottage pie, chicken supreme and vegetable soup, using both sensory (flavour profile method) and instrumental methods (GC-MS). The aim was to gain an understanding of the effect of reducing salt on key aroma volatiles and to investigate whether is was reflected in the sensory perception of the meals.

Table 5.1: Ingredient Declaration for Ready-Meals under Investigation

<table>
<thead>
<tr>
<th>Chicken Supreme</th>
<th>Cottage Pie</th>
<th>Vegetable Soup</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Water</td>
<td>1. Minced beef</td>
<td>1. Water</td>
</tr>
<tr>
<td>2. Chicken breast meat</td>
<td>2. Water</td>
<td>2. Vegetable stock</td>
</tr>
<tr>
<td>5. Mushrooms</td>
<td>5. Onion</td>
<td>5. Turnip</td>
</tr>
<tr>
<td>15. White pepper</td>
<td>15. Garlic puree</td>
<td>15. White pepper</td>
</tr>
</tbody>
</table>

1 Exact compositional make-up of ready-meals cannot be disclosed due to confidentiality.
1-15 = Abundance of each ingredient in each meal from most abundant (1) to least abundant (15).
5.3 Materials and Methods

5.3.1 Ready-Meal Samples

Three popular commercially available freeze-chilled ready-meals were selected for inclusion in this study. These ready-meals included a cottage pie - a savoury minced beef dish topped with potato; a chicken supreme - a chicken and mushroom dish in a cream and wine sauce; and a chunky vegetable soup. Two 500kg batches of each ready-meal type were manufactured by Dawn Fresh Foods Ltd., Fethard, Co. Tipperary, Ireland, according to their standard industrial protocols. A complete list of ingredients used in the manufacture of each ready-meal is listed in Table 5.1. One batch of each ready-meal was formulated to contain regular commercial levels of sodium whereas the second batch was reformulated to contain significantly reduced sodium levels. These levels are detailed in Table 5.2. Samples were pre-packaged in 250g – 300g portions and stored at -18°C upon receipt.

Table 5.2: Sodium Content and Salt Equivalents for Regular and Reduced Salt Ready-Meals

<table>
<thead>
<tr>
<th></th>
<th>Regular Salt Ready-Meal</th>
<th>Reduced Salt Ready-Meal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sodium (g/100g)</td>
<td>Salt Equivalent (g/100g)</td>
</tr>
<tr>
<td>Cottage Pie</td>
<td>0.32</td>
<td>0.80</td>
</tr>
<tr>
<td>Chicken Supreme</td>
<td>0.22</td>
<td>0.55</td>
</tr>
<tr>
<td>Vegetable Soup</td>
<td>0.37</td>
<td>0.93</td>
</tr>
</tbody>
</table>

\(^1\) Sodium content determined using atomic absorption spectrophotometer using method described by Mitchell et al., 2011b. \(^2\) Salt equivalent determined by multiplying sodium content by 2.5.

5.3.2 Sample Preparation - Sensory Profiling

Two to three days before sensory evaluation the required number of regular and reduced salt ready-meals were removed from the freezer and tempered to chill at 4°C. On each testing day the ready-meals were removed from chilled storage and individually cooked, 7 minutes for both the chicken supreme and vegetable soup, and 9 minutes for the cottage pie, on full power in a microwave oven (850watt) as recommended by the manufacturer. The cooked meals were subsequently evenly...
distributed in approximately 35g portions into circular foil cases (50mm diameter). All samples were individually presented to panellists in a random order on white paper plates labelled with three digit random codes. Plastic cutlery, napkins and water, to palate cleanse were also provided.

Table 5.3: Sensory Profiling Attributes and Definitions in Their Order of Perception as Agreed upon by Panel Consensus for Cottage Pie Ready-Meals

<table>
<thead>
<tr>
<th>Descriptive Attributes</th>
<th>Abbreviations</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oily aroma</td>
<td>OA</td>
<td>Typical aroma from heated oil, grease or fat</td>
</tr>
<tr>
<td>Uneven surface colour</td>
<td>USC</td>
<td>Uneven mix of colours on surface of meal</td>
</tr>
<tr>
<td>Oily surface shine</td>
<td>OSS</td>
<td>Visible oily/greasy shine on surface layer of meal</td>
</tr>
<tr>
<td>Translucent appearance</td>
<td>TA</td>
<td>Transparent/watery appearance to potato layer</td>
</tr>
<tr>
<td>Butter flavour</td>
<td>BuF</td>
<td>Typical butter flavour e.g. real butter</td>
</tr>
<tr>
<td>Oily flavour</td>
<td>OF</td>
<td>Typical oil flavour e.g. olive oil</td>
</tr>
<tr>
<td>Potato flavour</td>
<td>PoF</td>
<td>Typical potato flavour e.g. mashed potatoes</td>
</tr>
<tr>
<td>Beef flavour</td>
<td>BF</td>
<td>Typical beef flavour e.g. roast beef</td>
</tr>
<tr>
<td>Salt flavour</td>
<td>StF</td>
<td>Typical salt flavour e.g. sodium chloride</td>
</tr>
<tr>
<td>Pepper flavour</td>
<td>PF</td>
<td>Typical pepper flavour e.g. white pepper</td>
</tr>
<tr>
<td>Sweet flavour</td>
<td>SwF</td>
<td>Typical sweet flavour e.g. sugar/sucrose</td>
</tr>
<tr>
<td>Aftertaste</td>
<td>At</td>
<td>Residual taste in mouth after ingestion of soup</td>
</tr>
<tr>
<td>Persistent aftertaste</td>
<td>PAAt</td>
<td>Persistent taste left in mouth several minutes after ingestion of soup</td>
</tr>
</tbody>
</table>

Abbreviations in brackets correspond to descriptive attribute names in GPA plot in Figure 5.2.

5.3.3 Sensory Profiling Analysis

Sensory profiling analyses (flavour profile method) were conducted on the regular and reduced salt versions of the three different ready-meal types according to the guidelines set out in the international standards ISO 6658: 2005(E) and ISO 6564: 1985(E). The panel which consisted of eight members, 6 male and 2 female in their twenties and thirties, were selected and trained according to the guidelines set out in ISO 8586-1: 1993(E) and in ISO 6564:1985(E). The panellists’ were selected from staff and students of the Teagasc Food Research Centre, Ashtown, Dublin, all of whom had previous sensory evaluation experience. The main criterion for inclusion
into the panel following a pre-screening questionnaire was availability and willingness to consume ready-meals. Screening by a series of acuity and discrimination tests (ISO 8586-1) was conducted and panellists were required to correctly complete all sessions to be eligible for inclusion in the study. In a pre-test session, the selected panel members were calibrated using samples that were considered most different for each of the selected sensory descriptors typical of the ready-meals being profiled (Johansen et al., 2010). The panel were trained over a period of eighteen 1½-2 hour sessions. A set of descriptors were developed and defined for each ready-meal during training, which included the significant appearance, flavour and aroma attributes of the meals, their order of perception and intensity. A total of 13 cottage pie descriptors (Table 5.3), 10 chicken supreme descriptors (Table 5.4) and 12 vegetable soup descriptors (Table 5.5) were developed and agreed upon by panel consensus. Each ready-meal type (i.e. chicken supreme or cottage pie) was evaluated on a separate day and all evaluations were carried out at the same time each day, in a sensory laboratory with individual testing booths equipped with serving windows and controlled lighting. The panellists were presented with 2 samples per session, one regular salt ready-meal sample and one reduced salt ready-meal sample. The two ready-meals types were presented to the panel in random order for intensity scaling, however, within each meal type a randomized balanced sample presentation order was used to minimize bias due to first-order and carry-over effects (MacFie et al., 1989; Baxter et al., 2005). This resulted in a total of 4 replications being conducted on each meal (one presentation of each of AB, AA, BA and BB). Intensity ratings for each of the descriptive terms were scored using a 15cm line scale ranging from low intensity (0cm) corresponding to the word anchor ‘none’ to high intensity (15cm) corresponding to the word anchor ‘strong’. Panel members individually tasted and scaled each sample using the 15cm line scale.
### Table 5.4: Sensory Profiling Attributes and Definitions in Their Order of Perception as Agreed upon by Panel Consensus for Chicken Supreme Ready-Meals

<table>
<thead>
<tr>
<th>Descriptive Attributes</th>
<th>Abbreviations</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy aroma</td>
<td>DA</td>
<td>Typical aroma from dairy products e.g. cream, milk and yogurt</td>
</tr>
<tr>
<td>Oily aroma</td>
<td>OA</td>
<td>Typical aroma from heated oil, grease or fat</td>
</tr>
<tr>
<td>Uneven surface colour</td>
<td>USC</td>
<td>Uneven mix of colours on surface of meal</td>
</tr>
<tr>
<td>Surface skin</td>
<td>SS</td>
<td>Layer of coagulated skin on surface of meal</td>
</tr>
<tr>
<td>Cream flavour</td>
<td>CF</td>
<td>Typical cream flavour e.g. whipped cream</td>
</tr>
<tr>
<td>Mushroom flavour</td>
<td>MF</td>
<td>Typical mushroom flavour e.g. sautéed mushrooms</td>
</tr>
<tr>
<td>Wine Flavor</td>
<td>WF</td>
<td>Typical wine flavour e.g. white wine</td>
</tr>
<tr>
<td>Onion Flavor</td>
<td>OnF</td>
<td>Typical onion flavour e.g. cooked or fried onions</td>
</tr>
<tr>
<td>Salt flavour</td>
<td>StF</td>
<td>Typical salt flavour e.g. sodium chloride</td>
</tr>
<tr>
<td>Sweet flavour</td>
<td>SwF</td>
<td>Typical sweet flavour e.g. sugar/sucrose</td>
</tr>
</tbody>
</table>

1 Abbreviations in brackets correspond to descriptive attribute names in GPA plot in Figure 5.4.

### Table 5.5: Sensory Profiling Attributes and Definitions in Their Order of Perception as Agreed upon by Panel Consensus for Vegetable Soup Ready-Meals

<table>
<thead>
<tr>
<th>Descriptive Attributes</th>
<th>Abbreviations</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrot aroma</td>
<td>CA</td>
<td>Typical carrot aroma e.g. cut and cooked carrots</td>
</tr>
<tr>
<td>Green colour</td>
<td>GC</td>
<td>Typical green colour e.g. garden peas</td>
</tr>
<tr>
<td>Yellow colour</td>
<td>YC</td>
<td>Typical yellow colour e.g. ripe banana skin</td>
</tr>
<tr>
<td>Surface oiliness</td>
<td>SO</td>
<td>Layer/film of oil present on the surface of soup</td>
</tr>
<tr>
<td>Translucent appearance</td>
<td>TA</td>
<td>Transparent/watery appearance to soup</td>
</tr>
<tr>
<td>Salt flavour</td>
<td>StF</td>
<td>Typical salt flavour e.g. sodium chloride</td>
</tr>
<tr>
<td>Pepper flavour</td>
<td>PF</td>
<td>Typical pepper flavour e.g. white pepper</td>
</tr>
<tr>
<td>Sweet flavour</td>
<td>SwF</td>
<td>Typical sweet flavour e.g. sugar/sucrose</td>
</tr>
<tr>
<td>Onion flavour</td>
<td>OnF</td>
<td>Typical onion flavour e.g. cooked or fried onions</td>
</tr>
<tr>
<td>Overall flavour</td>
<td>OvF</td>
<td>Strength and intensity of flavours present</td>
</tr>
<tr>
<td>Overall flavour complexity</td>
<td>OvFC</td>
<td>Variety and mix of flavours present</td>
</tr>
<tr>
<td>Aftertaste</td>
<td>At</td>
<td>Residual taste in mouth after ingestion of soup</td>
</tr>
</tbody>
</table>

1 Abbreviations correspond to descriptive attribute names in GPA plot in Figure 5.6.
5.3.4 Isolation of Volatile Compounds using Headspace Solid-Phase-Microextraction (SPME)

Headspace volatiles released from the ready-meals were concentrated using solid phase microextraction (SPME) and subsequently determined by gas chromatography mass spectrometry (GC-MS). Similar to sensory analysis, 2-3 days before SPME/GC-MS analysis the required number of ready-meals were removed from the freezer and tempered to chill at 4°C. Prior to carrying out SPME a series of experiments were conducted to determine the optimal sampling conditions in terms of reproducibility and the time required for equilibration to occur between the SPME fiber and the headspace volatiles. The conditions described below represent the best compromise between reduced sampling time and increased reproducibility. On the day of analysis aqueous ready-meal homogenates (25% w/v) were prepared by homogenizing a 12.5g sample of each ready-meal with 37.5ml of MilliQ water in 50ml centrifuge tubes (Sarstedt Aktiengesellschaft and Co., Germany) using an Omni-prep multi-sample homogenizer (Omni International, Marietta, GA, USA) for 1min at 20000rpm. Care was taken to include components of each part of the ready-meal into the 12.5g sample. 10mls of each homogenate was transferred into a 25ml flask with an open centre propylene screw cap and Teflon faced silicone septum (Supelco, Bellefonte, PA, USA). The sample was then equilibrated for 10mins in a water bath heated to 40°C and an 85µm stableFlex Carboxen/Polydimethylsiloxane (PDMS) SPME fiber exposed to the sample headspace for 120mins for both cottage pie and chicken supreme ready-meals, and 90mins for vegetable soup ready-meals, with constant stirring at 250rpm using a magnetic octagonal stirring bar (7.9mm diameter x 22.2mm length; Fisher, Pittsburgh, PA, USA). After sampling the headspace volatiles, the fiber was retracted into the SPME fiber-holder and then immediately transferred to the injection port of the GC-MS. Two samples were taken from each of the cottage pie, chicken supreme and vegetable soup ready-meals and a total of 2 ready-meals were used per meal type, resulting in 4 replications for each of the regular and reduced salt meals.

5.3.5 Volatile Profile Analysis

Analysis of the volatile compounds adsorbed on the fiber was carried out using a Varian 3800 GC system coupled to a Varian Saturn 2000 ion trap mass spectrometer
Chapter 5

GC-MS Flavour Profiling

(Varian Chromatography Systems, Walnut Creek, CA, USA). Separation of the volatiles was accomplished on a ZB-wax column (60m x 0.25mm i.d., 0.25µm film) (Zebron GC Columns, Phenomenex Inc, Torrance, CA, USA). Helium, at a flow rate of 1.2ml/minute, was used as carrier gas. Thermal desorption of the compounds took place in the GC injection port (1079 Programmable Temperature Vaporizing (PTV) Injector), equipped with a 0.75mm i.d. splitless glass liner, at 290°C for 7 minutes in splitless mode. The split valve was then opened (ratio 1:100) for a duration of 3 minutes and then returned to splitless mode for a further 13.5 minutes. The fiber remained in the injection port for approximately 2 minutes. The oven temperature was programmed at an initial temperature of 45°C for 4 minutes, increased to 150°C at a rate of 10°C/minute and then further increased to a final temperature of 250°C at a rate of 25°C/minute at which point the temperature remained constant for 5 minutes. The mass spectrometer was tuned using the autotune procedure and masses from m/z 40 to 600 were recorded after electron impact ionization under EI auto mode. Peak areas were analyzed and quantified using the Varian star chromatography workstation software (v 5.0; Varian Chromatography Systems). Compounds were identified by the use of authenticated standards and by matching their mass spectra with the data stored in the NIST library of standard compounds. Additionally, linear retention indices (LRI) were calculated for each compound according to the van Den Dool and Kratz equation (1963) using C₈–C₂₀ n-alkanes as reference compounds and compared with LRI’s of authenticated standards and published data. The data reported is the mean area of 4 replicates for each individual peak in the total ion chromatogram (TIC).

5.3.6 Analysis of Data
Senstools version 3.1.4 software (OP&P Product Research BV, Utrecht, The Netherlands) was used to carry out descriptive statistical analysis on all sensory profiling data - the means, medians, percentiles and standard deviations were calculated to get an overall impression of the products. For each ready-meal (cottage pie, chicken supreme and vegetable soup) paired t-tests were applied to all sensory descriptors to evaluate the effects of reducing salt on each meal. Paired t-tests were applied to the individual peak areas to evaluate the effect that reducing salt levels had on the volatile profiles of each meal. Multivariate data analysis was preformed on the
raw data from each meal by treating each of the 4 replicates as individual products. Generalized procrustes analysis (GPA) was carried out using both Senstools version 3.1.4 software (OP&P Product Research BV, Utrecht, The Netherlands) and XLSTAT version 2010.5.01 software (Addinsoft, New York, USA) and was used to map the sensory descriptors with both the reduced salt and regular salt ready-meals. GPA was also used to study the inter-relationships between samples and panellists and to detect any divergences between panellists in the consensus configuration of the samples. Correlations between volatile measurements (X-variables) and sensory data (Y-variables) were investigated by Partial Least Squares Regression (PLSR) using the XLSTAT version 2010.5.01 software (Addinsoft, New York, USA).

5.4 Results and Discussion

5.4.1 Assessor Statistics

Procrustes analysis of variance (PANOVA) of the regular and reduced salt vegetable soup revealed that both the translation and scaling steps in the analysis had the most significant effect on the consensus space solution (Table 5.6). In particular, the translation of the individual panellist configuration to a common origin was found to be highly significant (p<0.0001) and is equivalent to eliminating the panellist effect (Sinesio and Moneta, 1997). The scaling step, relating to differences in the usage by panellists of the intensity scale had a smaller yet still significant (p<0.05) effect, implying that the panels’ usage of the intensity scale differed.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Translation</td>
<td>91</td>
<td>1781.16</td>
<td>19.57</td>
<td>10.0977</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Rotation/reflection</td>
<td>546</td>
<td>897.47</td>
<td>1.64</td>
<td>0.8480</td>
<td>0.8541</td>
</tr>
<tr>
<td>Scaling</td>
<td>7</td>
<td>70.43</td>
<td>10.06</td>
<td>2.1906</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Residual</td>
<td>84</td>
<td>162.82</td>
<td>1.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>728</td>
<td>2911.88</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Df = Degrees of freedom; 2 SS = Sum of squares; 3 MS = Mean squares; 4 F = F-statistic; 5 P = P-value.
A closer look at the scaling factors, a measure of the scoring range used by panellists (Sinesio and Moneta, 1997), across each vegetable soup is shown is Table 5.7. Values greater than 1 in Table 5.7 are a sign that a panellist used a shorter range of the intensity scale while a value less than 1 indicates that the panellist used a wider range of the intensity scale (Byrne et al., 2001). Upon closer inspection of this data differences between the scaling factors appeared small and therefore, all sensory panelists’ results were included in all further analysis. The rotation/reflection step for differences in the panelists interpretation of terms was found not to be significant (p>0.05; Table 5.6) illustrating that the assessors were well trained in the use of the developed terminology. Similar PANOVA results were obtained for both the cottage pie and chicken supreme ready-meals with the translation and scaling steps found to be significant therefore, these results are not shown.

<table>
<thead>
<tr>
<th>Panellist Number</th>
<th>Cottage Pie</th>
<th>Chicken Supreme</th>
<th>Vegetable Soup</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.22</td>
<td>1.07</td>
<td>1.02</td>
</tr>
<tr>
<td>2</td>
<td>0.96</td>
<td>1.03</td>
<td>1.10</td>
</tr>
<tr>
<td>3</td>
<td>1.10</td>
<td>0.94</td>
<td>1.09</td>
</tr>
<tr>
<td>4</td>
<td>1.28</td>
<td>1.02</td>
<td>1.14</td>
</tr>
<tr>
<td>5</td>
<td>1.06</td>
<td>0.92</td>
<td>0.89</td>
</tr>
<tr>
<td>6</td>
<td>0.91</td>
<td>0.94</td>
<td>0.98</td>
</tr>
<tr>
<td>7</td>
<td>0.99</td>
<td>1.23</td>
<td>1.17</td>
</tr>
<tr>
<td>8</td>
<td>1.05</td>
<td>1.04</td>
<td>0.92</td>
</tr>
</tbody>
</table>

5.4.2 Sensory Profiling

5.4.2.1 Cottage Pie

Thirteen descriptive sensory attributes were developed, defined and scaled by the panel for both cottage pie ready-meals, results of which are presented in Figure 5.1. From Figure 5.1 we can see that of the 13 descriptive terms, nine were found to be
significantly different by paired t-tests. In terms of flavour, the reduced salt ready-meal was found to have a significantly weaker “salt flavour” (p<0.005), a significantly reduced “pepper flavour” (p<0.01) and a much more distinctive “oily flavour” (p<0.005). The reduced salt meal was also seen to have a more significant “uneven surface colour” (p<0.005), an “oiler surface shine” (p<0.01) and a greater “translucent appearance” (p<0.01). These attributes and indeed the increased “oily flavour” were all attributed to the fact that the reduced salt meal had a higher concentration of visible oil present in comparison to the regular salt meal.

Figure 5.1: Sensory Profile (Mean Scores) for Cottage Pie Ready-Meals with Regular Salt (0.80g/100g) and Reduced Salt (0.35g/100g) Concentrations

This increased level of oil in the reduced salt meal ultimately resulted in the meal having an oilier taste, a surface colour that was more uneven due to presence of oil which thus, resulted in the meal appearing more translucent with an oilier surface shine. This result is of no surprise as one of the main roles of salt in processed meat products is the solubilisation of myofibrillar protein (Desmond, 2006). During
cooking of these products the solubilised protein forms a micelle around fat globules present hence retaining the fat (Monaghan and Troy, 1997; Desmond, 2006). However, reducing the level of salt in food can effect solubilisation which results in the formation of less micelles thus releasing more free fat from the product. Despite these findings the regular salt meal was found to have a significantly oilier aroma (p<0.05) than its reduced salt counterpart. This result can again be attributed to the effect that salt has on solubilisation, however, in this case the increased level of salt in the regular salt meal may have resulted in more lipophilic volatiles being released into the headspace and thus an “oilier aroma”. Finally, the reduced salt meal was found to have a significant “aftertaste” (p<0.05) in comparison to the regular salt cottage pie and this “aftertaste” was found to be “persistent” (p<0.05) by the panel.

Figure 5.2: GPA Group Average Consensus Plot (Dimension 1 (79.71%) Vs Dimension 2 (5.93%)) for Cottage Pie Ready-Meals

Abbreviations correspond to descriptive attributes listed in Table 5.3.

The GPA consensus plot generated for the first two dimensions accounted for 85.64% of the total variance: dimension 1 accounted for 79.71% of the total variance
and dimension 2 accounted for only 5.93% (Figure 5.2). Good agreement was observed among the sample replicates for both the regular salt and reduced salt cottage pies. The regular salt ready-meal replicates were clustered together on the negative axis of dimension 1 and this meal was found to be well correlated with the attributes “salt flavour” (-1.0), “persistent aftertaste” (-0.95), “pepper flavour” (-0.84) and “oily aroma” (-0.80). The reduced salt cottage pie replicates were found clustered together on the positive axis of dimension 1 and this meal was found to be associated with the descriptive attributes “uneven surface colour” (0.96), “oily flavour” (0.95), “oily surface shine” (0.95) and “translucent appearance” (0.87). Dimension 2 was best defined by the attributes “beef flavour” (0.81) and “sweet flavour” which were associated with the regular salt meal (0.71).

Reducing salt content in the cottage pie appeared to increase the “oily flavour” of the meal and make it appear more “translucent” with a more “uneven surface colour” and an “oilier surface shine”. The salt and pepper flavours were decreased along with the oily aroma of the meal. Reducing the salt content in the meal formulation also had the effect of increasing the aftertaste associated with the meal. While it was fully understood by the panel that the flavour profile method is a procedure for describing and assessing the flavour of a product, the panel felt strongly about the inclusion of appearance attributes due to the obvious exterior differences observed between the two ready-meals. As this is not the norm when conducting this method every effort was made to ensure that the organization and administration of this method in terms of flavour attributes was not affected in any way by the inclusion of appearance attributes. The significant differences (p<0.01) observed between the ready-meals for each of the 3 included appearance attributes further warranted their inclusion. The increased level of oil in the reduced salt meal as a result of decreased solubilisation ultimately resulted in the appearance as well as the flavour and aroma of the meal being affected.

5.4.2.2 Chicken Supreme
Two commercial chilled chicken supreme meals, one regular salt ready-meal and one reduced salt ready-meal, were assessed by a trained sensory profiling panel using 10 sensory descriptors. From Figure 5.3 it can be seen that, in general, the reduced salt
chicken supreme had a weaker flavour profile in comparison to its regular salt counterpart with the exception of sweet flavour, which was somewhat more pronounced in the reduced salt meal. Paired t-tests showed significant differences (p<0.05) existed among the two ready-meals for 5 of the 10 sensory descriptors.

**Figure 5.3: Sensory Profile (Mean Scores) for Chicken Supreme Ready-Meals with Regular Salt (0.55g/100g) and Reduced Salt (0.33g/100g) Concentrations**

In particular, the reduced salt ready-meal was found to have a significantly weaker “oily aroma” (p<0.05) and a more “uneven surface colour” (p<0.05) in comparison to its regular salt counterpart. The flavour attributes of the meal were also significantly affected by the reduction of salt in the ready-meal formulation, more specifically, the reduced salt ready-meal had a significantly weaker “salt flavour” (p<0.005), “wine flavour” (p<0.005) and “mushroom flavour” (p<0.01).
The GPA consensus plot generated for the first two dimensions is shown in Figure 5.4. This two dimensional plot accounted for 87.25% of the total variance: dimension 1 accounted for 82.51% of the total variance and dimension 2 accounted for only 4.74%. Good agreement was observed among the sample replicates for both the regular salt and reduced salt chicken supreme. The regular salt ready-meal replicates were clustered together on the negative axis of dimension 1 and this meal were found to be correlated with the attributes “salt flavour” (-1.0), “wine flavour” (-0.98), “oily aroma” (-0.94), “mushroom flavour” (-0.89), “surface skin” (-0.86) and “dairy aroma” (-0.79). In contrast, the reduced salt chicken supreme replicates were found clustered together on the positive axis of dimension 1 and this meal was found to be associated with the descriptive attributes “uneven surface colour” (0.99) and “sweet flavour” (0.88). Dimension 2 was best defined by the attribute “cream flavour” (-0.44) however, this attribute could not be linked to either the regular salt or reduced salt ready-meals.

**Figure 5.4: GPA Group Average Consensus Plot (Dimension 1 (82.51%) Vs Dimension 2 (4.74%)) for Chicken Supreme Ready-Meals**

Abbreviations correspond to descriptive attributes listed in Table 5.4.
Reducing the salt content in the chicken supreme appeared to decrease the strength of flavours that were present in the original meal such as “salt flavour”, “wine flavour” and “mushroom flavour”, while at the same time increasing the “sweet flavour”. The notable “oily aroma” associated with the meal became weaker with the reduction of salt in the formulation, while the “surface colour” became more uneven. Once again while it was fully understood by the panel that the flavour profile method is a procedure for describing and assessing the flavour of a product, the panel felt strongly about the inclusion of appearance attributes due to the obvious exterior differences observed between the two ready-meals. The significant difference (p<0.05) observed between ready-meals in terms of the attribute “uneven surface colour” further warranted their inclusion. It was found that reducing salt in the chicken supreme had the affect of significantly increasing the unevenness of the surface colour while at the same time decreasing the appearance of a surface skin. These findings suggest a potential effect of salt reduction on the appearance of ready-meals.

5.4.2.3 Vegetable Soup

Two commercial chilled vegetable soups, one regular salt soup and one reduced salt soup, were described and differentiated by a trained sensory profiling panel using 12 sensory descriptors. From Figure 5.5 it can be seen that in general, the reduced salt vegetable soup had a weaker overall sensory profile in comparison to its regular salt counterpart, with the exceptions of sensory attributes “green colour”, “sweet flavour” and “pepper flavour”, which were more pronounced in the reduced salt soup and “surface oiliness” which was almost identical in both meals. Paired t-test revealed notable significant differences (p<0.05) existed between the two soups for 8 of the 12 sensory descriptors. In particular, the reduced salt soup was found to have a significantly weaker “overall flavour” (p<0.01) which included a significantly reduced “salt flavour” (p<0.005), a more pronounced “sweet flavour” (p<0.005), a reduced “aftertaste” (p<0.05) and an “overall flavour complexity” which was weakened, as well as a fainter “carrot aroma” (p<0.005), a less distinct “yellow colour” (p<0.005), and a more prominent “green colour” (p<0.05).
Figure 5.5: Sensory Profile (Mean Scores) for Vegetable Soup Ready-Meals with Regular Salt (0.93g/100g) and Reduced Salt (0.45g/100g) Concentrations

The GPA consensus plot generated for the first two dimensions is shown in Figure 5.6. This two dimensional solution accounted for 86.29% of variance: dimension 1 accounted for 81.19% of the total variance and dimension 2 accounted for only 5.10%. Good agreement was seen among the sample replicates with the regular salt vegetable soup in particular being closely clustered together on the negative axis of dimension 1, while the reduced salt soup samples were more broadly clustered together on the positive axis of dimension 1. The regular salt vegetable soup was found to be strongly correlated with “salt flavour” (-1.00), “yellow colour” (-0.98), “carrot aroma” (-0.97), “overall flavour” (-0.93) and “aftertaste” (-0.84) while the reduced salt vegetable soup was correlated with “sweet flavour” (0.98), “green colour” (0.90) and “pepper flavour” (0.82) in dimension 1. Dimension 2 was best defined by the attribute “surface oiliness” (0.49) which was linked with the reduced salt vegetable soup.
Reducing salt in the soup appeared to have the effect of intensifying other flavours present in the original soup such as “sweet” and “pepper” type flavours, while at the same time decreasing the salty flavour. The notable “carrot” aroma associated with the regular salt soup became weaker with the reduction of salt in the soup formulation. While it was fully understood by the panel that the flavour profile method is a procedure for describing and assessing the flavour of a product, the panel felt strongly about the inclusion of appearance attributes due to the clear colour differences observed between the two soups. The significant differences observed between the colour attributes for the regular and reduced salt ready-meals further warranted their inclusion. It was found that reducing salt in the vegetable soup had the affect of significantly reducing the “yellow colour” (p<0.005) associated with the meal while at the same time significantly increasing the “green colour” (p<0.05) of the soup. This unexpected result revealed that lowering salt in the vegetable soup
affected the appearance attributes of the meal, an effect which could potentially be seen in similar reduced salt soup products.

5.4.3 Volatile Analysis
The volatiles released from the different reduced and regular salt ready-meals were analyzed to understand how volatile profiles contributed to the flavour of the different meals, results of which are presented in Table 8, 9, 10.

5.4.3.1 Cottage Pie
The major ingredients used in the cottage pie formulation are listed in Table 5.1. Minced beef was the main ingredient used while garlic puree was present in the lowest amount in the formulation. SPME-GC-MS analysis resulted in ten volatile compounds being identified corresponding to the 10 major peaks present in both the regular and reduced salt cottage pie. These 10 compounds can be broadly categorized into five groups; terpenes, aldehyde, alcohols, organosulfurs and hydrocarbons (Table 5.8). Terpenes were the largest group of compounds present in both the regular and reduced salt cottage pie. These compounds as a group were present in slightly higher amounts in the reduced salt cottage pie in comparison to the regular salt meal and comprised of over half of the all identified compounds total peak area (28.88% out of a total of 53.30% - Table 5.8). Limonene, the most abundant of the 4 terpenes identified was present in significantly different amounts (p<0.01) in the two ready-meals with the reduced salt cottage pie containing double the amount of limonene compared with its regular salt counterpart. This compound has previously been identified in numerous cottage pie ingredients such as beef stock (Snitkjær et al., 2010), minced beef (Rivas-Cañedo et al., 2009), boiled potatoes (Blanda et al., 2010), flour (Maeda et al., 2009), milk (Valero et al., 1999) including skim milk powder (Shiratsuchi et al., 1994) and yeast (Comuzzo et al., 2006). Limonene together with α-pinene have also been identified in other ingredients including the tomato paste (Feudo et al., 2011), beef (Calkins and Hodgen, 2007), potato (Oruna-Concha et al., 2002), white pepper (Plessi et al., 2002) and butter (Povolo and Contarini, 2003). Like limonene, α-pinene was also present in significantly higher concentrations (p<0.05) in the reduced salt ready-meal. Conversely, β-caryophyllene was present in a higher amount in the regular salt ready-meal and has previously been identified in white pepper (Plessi et al., 2002). P-Cymene was present in a slightly higher
concentration in the reduced salt ready-meal, however, when these figures were converted to ‘% total area’ p-cymene made up a greater percentage of total area of the regular salt ready-meal.

Table 5.8: Peak Areas (x 10^5) and Percentage of Total Area\(^1\) of Headspace Volatile Compounds Identified in Regular and Reduced Salt Cottage Pie Ready-Meals

<table>
<thead>
<tr>
<th>LRI(^1)</th>
<th>Compound Name(^2)</th>
<th>I.D.(^3)</th>
<th>Peak Area(^4)</th>
<th>% Total Area(^4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Regular salt</td>
<td>Reduced salt</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Regular salt</td>
<td>Reduced salt</td>
</tr>
<tr>
<td>614</td>
<td>A. 3,4-Dimethylhexane</td>
<td>MS, LRI</td>
<td>0.96</td>
<td>1.87</td>
</tr>
<tr>
<td>809</td>
<td>B. 2-Methyl propanol</td>
<td>MS, LRI</td>
<td>8.43</td>
<td>11.3</td>
</tr>
<tr>
<td>931</td>
<td>C. Methyl allyl sulfide</td>
<td>MS, LRI</td>
<td>1.31</td>
<td>1.13</td>
</tr>
<tr>
<td>1009</td>
<td>D. α-Pinene *</td>
<td>MS, LRI, ST</td>
<td>2.32</td>
<td>4.90</td>
</tr>
<tr>
<td>1094</td>
<td>E. Hexanal</td>
<td>MS, LRI, ST</td>
<td>5.51</td>
<td>6.24</td>
</tr>
<tr>
<td>1146</td>
<td>F. Diallyl sulfide *</td>
<td>MS, LRI</td>
<td>2.18</td>
<td>3.45</td>
</tr>
<tr>
<td>1188</td>
<td>G. (R)-(+) -Limonene **</td>
<td>MS, LRI, ST</td>
<td>3.83</td>
<td>8.53</td>
</tr>
<tr>
<td>1258</td>
<td>H. p -Cymene</td>
<td>MS, LRI, ST</td>
<td>1.44</td>
<td>1.51</td>
</tr>
<tr>
<td>1560</td>
<td>I. β-Caryophyllene</td>
<td>MS, LRI, ST</td>
<td>5.81</td>
<td>3.92</td>
</tr>
<tr>
<td>1754</td>
<td>J. 2-Undecenal **</td>
<td>MS, LRI</td>
<td>4.25</td>
<td>1.23</td>
</tr>
<tr>
<td></td>
<td>Terpenes (Total)</td>
<td></td>
<td>13.40</td>
<td>18.86</td>
</tr>
<tr>
<td></td>
<td>Aldehydes (Total)</td>
<td></td>
<td>9.76</td>
<td>7.47</td>
</tr>
<tr>
<td></td>
<td>Alcohols (Total)</td>
<td></td>
<td>8.43</td>
<td>11.3</td>
</tr>
<tr>
<td></td>
<td>Organosulfurs (Total)</td>
<td></td>
<td>3.49</td>
<td>4.58</td>
</tr>
<tr>
<td></td>
<td>Hydrocarbons (Total)</td>
<td></td>
<td>0.96</td>
<td>1.87</td>
</tr>
<tr>
<td></td>
<td>Total Volatiles</td>
<td></td>
<td><strong>36.04</strong></td>
<td><strong>44.08</strong></td>
</tr>
</tbody>
</table>

\(^1\) LRI = Linear Retention Index calculated on a ZB-wax column using C\(_8\)-C\(_{20}\) alkane mix. \(^2\) Compound name labels A. – J. correspond to the volatile labels in PLSR plot in Figure 5.7. \(^3\) I.D. = Peak identification; ST, comparison of spectra with authenticated standards; MS, tentatively identified by matching mass spectra with the data stored in the NIST library; LRI, retention index agrees with authenticated standards or published data (Chung et al., 1994; Shimoda et al., 1995; Yu et al., 1993; Yu et al., 1989; Valim et al., 2003). \(^4\) Data are the average of 4 measurements. Significant difference levels calculated by XLSTAT version 2010.5.01 software using paired t-tests where * ≤ 0.05, ** ≤ 0.01 and *** ≤ 0.005.
This compound can be attributed to the presence of tomato paste in the ready-meal as it has previously been identified by a number of authors in tomato (Sieso and Crouzet, 1977), tomato juice (Servili et al., 2000), tomato pastes and fresh tomatoes (Feudo et al., 2011) as well as milk (Valero et al., 1999). Kjeldsen et al. (2003) reported that all 4 of these terpene hydrocarbons had odour sensations in water, with limonene, the most predominant terpene identified in the present study, having an odour threshold value (OTV) of 200ppb in water. β-caryophyllene was found to have an OTV of 160ppb, while β-pinene, similar to the α-pinene identified in the present study, had an OTV of 140ppb and p-cymene, the least abundant of these 4 terpenes identified in the present study, appeared to have the strongest impact on odour with an OTV of 13ppb (Kjeldsen et al., 2003). Therefore, despite limonene being the most abundant terpene in the ready-meals, it appears not to be as important to the overall flavour and aroma of the meal as some of the other terpenes, such as p-cymene, which were present in smaller amounts, a finding which is supported by Coultate (1999).

Aldehydes, in the form of hexanal and 2-undecenal, made up the second largest group of compounds in the meals. The latter of these, 2-undecanal, was present in significantly different concentrations (p<0.01) in the two ready-meals with the regular salt cottage pie containing over three times the amount present in the reduced salt meal. Previous authors have reported its presence in tomato juice (Servili et al., 2000), beef stock (Snitkjær et al., 2010) and boiled potatoes (Blanda et al., 2010) with Oruna-Concha et al. (2002) reporting the presence of undecenal in potatoes and Calkins and Hodgen (2007) reporting the presence of undec-4-enal in beef, two compounds similar to 2-undecenal. In comparison to 2-undecanal, hexanal was found in higher amounts in the reduced salt ready-meal, however, there was no significant difference between meals. Hexanal was the third largest individual compound present in both meals, which is of no surprise as it has previously been reported in many of the main ingredients used to make the cottage pie. More specifically, it has been identified in minced beef (Wettasinghe et al., 2001; Calkins and Hodgen, 2007; Kwon et al., 2008; Rivas-Cañedo et al., 2009; Rivas-Cañedo et al., 2011), beef stock (Snitkjær et al., 2010), potatoes (Blanda et al., 2010; Longobardi et al., 2011), tomato and tomato products (Sieso and Crouzet, 1977; Servili et al., 2000; Feudo et al., 2011) and dairy based ingredients (Shiratsuchi et al., 1994; Peterson and Reineccius, 2003; Povolo and Contarini, 2003; Biolatto et al., 2011).
Both hexanal and 2-undecenal are products of lipid oxidation and their greater abundance in the regular salt meals may be derived from the fact that salt is a known pro-oxidant (Torres et al., 1988). In addition, since minced beef is present in the highest quantity in the meal it is unlikely that the presence of these oxidation products may have arisen as a result of the oxidation of unsaturated lipids in the beef. Duckham et al. (2001) reported the OTV of hexanal as 4.5 ppb. Kalua et al., (2007) conducted a review of olive oil volatile compounds and reported previously determined OTV’s ranging from 75-300 µg/kg in oil. The deviation in these reported values makes it hard to interpret the importance of hexanal to the overall flavour and aroma of the meal; however, the low values reported by Duckham et al. (2001) in baked potatoes suggest it may have a significant effect given the high proportion of potato in the cottage pie.

2-Methyl propanol, the only alcohol identified, was the most abundant volatile present in both the regular and reduced salt ready-meals. It was present in a slightly higher concentration in the reduced salt meal, however, no significant difference was observed for 2-methyl propanol between meals. This compound has previously been reported in minced beef (Spanier and Boylston, 1994; Rivas-Cañedo et al., 2009), tomato juice, tomatoes and tomato paste (Servili et al., 2000; Feudo et al., 2011), butter (Povolo and Contarini, 2003) and flour (Maeda et al., 2009).

Two organosulfur compounds were identified in the regular and reduced salt cottage pie, methyl allyl sulfide and diallyl sulfide. The reduced salt cottage pie contained a significantly higher (p<0.05) content of diallyl sulfide compared with the regular salt meal; whereas, methyl allyl sulfide was more abundant in the regular salt meal, however, the difference between the meals was small. Allyl sulfides are said to constitute about 90% of garlic oil while methyl allyl sulfide is commonly linked to ‘garlic breath’ in those who consume garlic (Rowe, 1998). Therefore, the presence of these compounds in the meals can be attributed to the presence of both garlic (Calvo-Gómez et al., 2004) and onion (Boelens et al., 1971) in the ready-meal formulation. In a study on Thai fried chili paste Rotsatchakul et al. (2008) reported the OAV of diallyl sulfide as ranging from 978-1860 ng/mL, these high values imply its potential importance to the flavour and aroma of the meal.
3,4-Dimethylhexane was the least abundant of all the compounds detected in both meals, with the reduced salt meal containing almost double that found in the regular salt meal. Wettasinghe *et al.*, (2001) reported the presence of this compound in beef.

Of the 10 volatile compounds identified in the cottage pie ready-meal, 7 were found to have greater peak areas in the reduced salt ready-meal when compared with their regular salt equivalents. The effect observed in the reduced salt ready-meal was unexpected as salts are often routinely added to samples to increase the concentration of aroma volatiles in the vapour phase; therefore, a decrease in the levels of volatiles in the reduced salt meal was expected. A possible explanation lies in the fact that one of salts main roles in processed comminuted meat is the solubilisation of myofibrillar proteins which then form protein shells around any fat globules and other lipophilic components present (Monaghan and Troy, 1997; Desmond 2006). Retention or binding of flavour compounds to proteins in solution is more pronounced in the presence of fats (Chobert and Haertle, 1997; Voilley *et al.*, 2000; Guichard, 2002). In addition, the presence of proteins at the oil-water interface in emulsions has been shown to increase the resistance of the transfer of hydrophobic aroma compounds from oil to water and thus induces a decrease in flavour release and flavour perception (Guichard, 2002). Consequently, in the reduced salt meals, the level of protein-fat interactions in the product decreased resulting in less protein based encapsulation of hydrophobic volatile compounds thus, an increased release of volatile compounds into the headspace of the meal.

### 5.4.3.2 Chicken Supreme

The major ingredients in the chicken supreme are listed in Table 5.1. After water, chicken breast meat was the chief ingredient used whereas ground white pepper was the least abundant ingredient used in the formulation. Results of SPME-GC-MS analysis of the volatiles identified are listed in Table 5.9 with ‘Peak Areas’ and ‘% Total Area’ for each of the volatiles listed. Fourteen volatile compounds were identified corresponding to the 14 main peaks present in both the regular and reduced salt chicken supreme. These 14 compounds can be broadly categorized into ten groups; terpenes, aldehydes, furans, alcohols, organosulfurs, esters, ketones, heterocyclic aromatic compounds, hydrocarbons and amines (Table 5.9).
Table 5.9: Peak Areas (x 10^6) and Percentage of Total Area\(^1\) of Headspace Volatile Compounds Identified in Regular and Reduced Salt Chicken Supreme Ready-Meals

<table>
<thead>
<tr>
<th>LRI(^1)</th>
<th>Compound Name(^2)</th>
<th>I.D.(^3)</th>
<th>Regular salt</th>
<th>Reduced salt</th>
<th>Regular salt</th>
<th>Reduced salt</th>
</tr>
</thead>
<tbody>
<tr>
<td>614</td>
<td>A. 3,4-Dimethyl hexane</td>
<td>MS, LRI</td>
<td>0.55</td>
<td>0.69</td>
<td>1.22</td>
<td>1.15</td>
</tr>
<tr>
<td>809</td>
<td>B. 2-Methyl propanol</td>
<td>MS, LRI</td>
<td>2.43</td>
<td>3.73</td>
<td>5.49</td>
<td>6.23</td>
</tr>
<tr>
<td>902</td>
<td>C. Ethyl acetate</td>
<td>MS, LRI</td>
<td>2.28</td>
<td>3.19</td>
<td>5.15</td>
<td>5.53</td>
</tr>
<tr>
<td>946</td>
<td>D. Ethanol **</td>
<td>MS, LRI, ST</td>
<td>0.95</td>
<td>1.47</td>
<td>2.14</td>
<td>2.52</td>
</tr>
<tr>
<td>994</td>
<td>E. Pentan-2-one **</td>
<td>MS, LRI</td>
<td>1.02</td>
<td>1.79</td>
<td>2.30</td>
<td>3.10</td>
</tr>
<tr>
<td>1009</td>
<td>F. α-Pinene *</td>
<td>MS, LRI, ST</td>
<td>1.02</td>
<td>1.89</td>
<td>2.32</td>
<td>3.32</td>
</tr>
<tr>
<td>1033</td>
<td>G. Piperidine *</td>
<td>MS, LRI, ST</td>
<td>1.27</td>
<td>0.38</td>
<td>2.85</td>
<td>0.64</td>
</tr>
<tr>
<td>1094</td>
<td>H. Hexanal *</td>
<td>MS, LRI, ST</td>
<td>5.64</td>
<td>8.47</td>
<td>12.77</td>
<td>14.67</td>
</tr>
<tr>
<td>1146</td>
<td>I. Diallyl sulfide</td>
<td>MS, LRI</td>
<td>2.35</td>
<td>1.73</td>
<td>5.12</td>
<td>2.97</td>
</tr>
<tr>
<td>1188</td>
<td>J. (R)-(+) - Limonene *</td>
<td>MS, LRI, ST</td>
<td>3.93</td>
<td>5.68</td>
<td>8.87</td>
<td>9.76</td>
</tr>
<tr>
<td>1232</td>
<td>K. 2-Pentyl furan</td>
<td>MS, LRI</td>
<td>4.32</td>
<td>7.26</td>
<td>9.73</td>
<td>12.51</td>
</tr>
<tr>
<td>1260</td>
<td>L. Methyl pyrazine</td>
<td>MS, LRI</td>
<td>1.88</td>
<td>1.51</td>
<td>4.25</td>
<td>2.55</td>
</tr>
<tr>
<td>1355</td>
<td>M. Dimethyl trisulfide**</td>
<td>MS, LRI</td>
<td>1.03</td>
<td>1.38</td>
<td>2.33</td>
<td>2.38</td>
</tr>
<tr>
<td>1561</td>
<td>N. β-Caryophyllene</td>
<td>MS, LRI, ST</td>
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<td>1.28</td>
<td>3.57</td>
<td>2.16</td>
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|              | Terpenes (Total)      |              |              |              |              |
|--------------|-----------------------|--------------|--------------|--------------|
|              | 6.52                  | 8.85         | 14.76        | 15.24        |

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<td></td>
<td>0.55</td>
<td>0.69</td>
<td>1.22</td>
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<table>
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<td>1.27</td>
<td>0.38</td>
<td>2.85</td>
<td>0.64</td>
</tr>
</tbody>
</table>

Total Volatiles 30.24       40.45       68.11       69.49

\(^1\) LRI = Linear Retention Index calculated on a ZB-wax column using C\(_8\)-C\(_{20}\) alkane mix.
\(^2\) Compound name labels A. – N. correspond to the volatile labels in PLSR plot in Figure 5.8.
\(^3\) I.D. = Peak identification: ST, comparison of spectra with authenticated standards; MS, tentatively identified by matching mass spectra with the data stored in the NIST library; LRI, retention index agrees with authenticated standards or published data (Chung et al., 1994; Shimoda et al., 1995; Chung et al., 1993; Wong and Tie, 1993; Yu et al., 1989; Brunton et al., 2005; Kunert-Kirchhoff and Baltes, 1990; Jabalpurwala et al., 2010).
\(^4\) Data are the average of 4 measurements. Significant difference levels calculated by XLSTAT version 2010.5.01 software using paired t-tests where * ≤ 0.05, ** ≤ 0.01 and *** ≤ 0.005.
**Chapter 5**

Terpene hydrocarbons were the most abundant group of compounds identified in the headspace of both the regular and reduced chicken supreme, primarily limonene, in addition to β-caryophyllene and α-pinene. A reduction in the salt content of the ready-meal resulted in a slightly higher concentration of terpenes (15.24%) in comparison to the regular salt ready-meal (14.76%). Limonene and α-pinene were both found in significantly higher (p<0.05) concentrations in the reduced salt ready-meal, while β-caryophyllene was present in slightly higher concentrations in the regular salt meal however, there was no significant difference observed for this compound between samples. These terpenes have previously been identified by various authors in several ingredients used to manufacture the chicken supreme. More specifically, all 3 terpenes were probably derived from the lemon juice (Allegrone *et al.*., 2006) and white pepper (Plessi *et al.*., 2002) in the formulation. Limonene, the most abundant terpene, has also been reported in heated milk (Valero *et al.*., 1999), yeast (Comuzzo *et al.*., 2006) and flour (Maeda *et al.*., 2009). Both limonene and β-caryophyllene have been identified in skimmed-milk powder (Shiratsuchi *et al.*., 1994) and the compounds β-caryophyllene and α-pinene have been identified in mushroom (Borg-Karlson *et al.*., 1994). Kjeldsen *et al.*. (2003) reported that limonene, the most plentiful terpene identified, had an odour threshold value (OTV) of 200ppb in water. β-Caryophyllene was found to have an OTV of 160ppb, while β-pinene, similar to the α-pinene identified in the present study, had an OTV of 140ppb (Kjeldsen *et al.*., 2003). These threshold values are relatively high and therefore, suggest that these compounds may not have a significant effect on the aroma and flavour of the meal.

Hexanal, the only aldehyde identified in both meals, was present in significantly higher (p<0.05) concentrations in the reduced salt chicken supreme. Hexanal is a secondary oxidation product arising from unsaturated fatty acids and therefore, probably derives from the cooked chicken muscle. A number of authors have reported its presence in chicken breast meat (Du *et al.*., 2000; Wettasinghe *et al.*., 2001; Byrne *et al.*., 2002; Kwon *et al.*., 2008; Rivas-Cañedo *et al.*., 2009), as well as in cream (Schlutt *et al.*., 2007), mushrooms (MacLeod and Panchasara, 1983; Diaz *et al.*., 2002; Cho *et al.*., 2008;), whole and skimmed milk powder (Shiratsuchi *et al.*., 1994; Biolatto *et al.*., 2007) in addition to heated milk (Valero *et al.*., 1999), vegetable oil (Stashenko *et al.*.) and flour (Maeda *et al.*., 2009). Duckham *et al.*. (2001) reported the
OTV of hexanal to be equal to 4.5 ppb while Kalua et al. (2007) reported previously determined OTV’s in olive oil ranging from 75-300µg/kg in oil. The variation in these values makes it hard to determine the potential impact of hexanal on the flavour of the meal, however, low values equivalent to those reported by Duckham et al., (2001) would imply it is an important odorant.

Furans, in the form of 2-pentylfuran, was the third most abundant group of compounds in the chicken supreme. In fact 2-pentylfuran was present in the second highest amount in both the regular and reduced salt meals, however, no significant differences in concentration was seen for this compound among the meals. This compound has been identified in both yeast and flour (Comuzzo et al., 2006; Maeda et al., 2009) and has also been reported in chicken meat (Winne and Dirinck, 1996).

Ethanol, one of two alcohols identified, was present in significantly (p<0.01) higher concentrations in the reduced salt ready-meal. This compound in addition to the second alcohol identified, 2-methyl propanol, and the ester - ethyl acetate, can all largely be attributed to the presence of white wine (Genovese et al., 2009) in the chicken supreme formulation. 2-Methyl propanol and ethyl acetate were also both present in higher concentrations in the reduced salt ready-meals, however, no significant differences were observed for either compound. In addition to white wine (Jones et al., 2008), ethanol, 2-methyl propanol and ethyl acetate, have all also been reported in mushrooms (Díaz et al., 2002), chicken breast meat (Rivas-Cañedo et al., 2009) and flour (Maeda et al., 2009). Ethanol has also been identified in other studies in ingredients such as skim milk powder (Shiratsuchi et al., 1994), chicken breast meat (Kwon et al., 2008), onion bulbs (Prithiviraj et al., 2004), yeast (Comuzzo et al., 2006) and lemon juice (Allegrone et al., 2006). The odour activity values (OAV) of ethanol and propanol have been reported to equal 0.2 ppm (Attaire, 2009). These low odour activity values are an indication that the alcohols identified in the present study may not have had a significant impact on the aroma and flavour of the meal.

Two sulfide containing compounds were identified in the chicken supreme ready-meal, dimethyl trisulfide and diallyl sulfide. Dimethyl trisulfide was found in a significantly higher concentration (p<0.01) in the reduced salt ready-meal while diallyl sulfide was present in a higher concentration in the regular salt meal. Diallyl
sulfide is a major component of garlic (Grudzinski et al., 2001; Truong et al., 2009) and despite no garlic being listed on the ingredients declaration there is the possibility that it was present in the chicken stock. Excluding this theory, diallyl sulfides have been identified in onion (Boelens et al., 1971). Dimethyl trisulfide has also been identified in onion (Boelens et al., 1971; Kallio and Salorinne, 1990) in addition to flour (Maeda et al., 2009), mushroom (Borg-Karlson et al., 1994) and chicken (Byrne et al., 2002; Kwon et al., 2008). Duckham et al. (2001) reported the OTV of dimethyl trisulfide to be equal to 0.01ppb in baked potatoes, while Rotsatchakul et al. (2008) reported the OAV of dimethyl trisulfide to range from 311000-928800 ng/mL and diallyl sulfide as ranging from 978-1860 ng/mL. Dimethyl trisulfide’s extremely low OTV and extremely high OAV are an indication of the importance of sulfide compounds to the aroma of foods.

3,4-Dimethylhexane, piperidine and methyl pyrazine were all present in higher concentrations in the regular salt ready-meal, with piperidine concentrations showing a significant difference (p<0.05) between the samples. Piperidine is the volatile base formed when the pyridine alkaloid piperine, a naturally occurring substance found in black and white pepper, is hydrolyzed (Fuller and McClintock, 1986). The presence of this compound in the headspace of the chicken supreme can therefore, be associated with the presence of white pepper in the formulation. Wettasinghe et al., (2001) reported the presence of 3-methylpiperidine in chicken meat, as well as the hydrocarbon 3,3-dimethylhexane. Methyl pyrazine has been reported in several chicken supreme ingredients including mushroom (Borg-Karlson et al., 1994), chicken (Byrne et al., 2002), flour (Maeda et al., 2009) and yeast (Comuzzo et al., 2006). Young et al. (1996) reported the OTV of 2 pyrazine compounds in water namely 2-isobutyl-3-methoxypyrazine and 2-isopropyl-3-methoxypyrazine to be equal to 0.001 and 0.0002 µg/l respectively. Although these are not the compounds identified in the present study their low OTV are an indication of their possible effect on the flavour of the chicken supreme.

Pentan-2-one, the only ketone identified, was present in a significantly higher concentration (p<0.05) in the reduced salt ready-meal. This compound was identified in the dairy based ingredients cream and milk (Wong and Patton, 1962; Valero et al., 1999) in addition to yeast (Comuzzo et al., 2006).
Of the 14 volatile compounds identified in the chicken supreme ready-meal, 10 were found to have greater peak areas in the reduced salt ready-meal when compared with their regular salt equivalents. The effect observed in the reduced salt ready-meal was unexpected as salts are often routinely added to samples to increase the concentration of aroma volatiles in the vapour phase; therefore, a decrease in the levels of volatiles in the reduced salt meal was expected. However, the levels of salt routinely added to samples to increase the concentration of aroma volatiles are far in excess of the levels found in both the regular and reduced salt chicken supreme. For example, Rocha et al. (2001) found the addition of 8g of salt into wine samples significantly increased volatile peak areas, while Flores et al. (2003) found the addition of 80g/l sodium chloride more than doubled the concentration of volatiles present in the headspace of dry-cured meat products. Therefore, the level of salt present in the regular and reduced salt chicken supreme (0.55 and 0.35% salt respectively) may not have been significant enough to produce a ‘salting-out’ effect and the observed differences in volatile concentrations may be attributed to other factors affecting the meal.

5.4.3.3 Vegetable Soup

The chief ingredients in the formulation that contribute to the unique flavour of the commercial vegetable soup used in the present study included: carrot, potato, turnip, onion and celery, with carrot being the main ingredient of those listed and celery the least abundant (Table 5.1). Other ingredients potentially important to the flavour of the soup included salt, parsley, white pepper, butter, milk, cream and vegetable oil.

Results of SPME-GC-MS analysis of the volatiles identified are listed in Table 5.10 with ‘peak areas’ and ‘% of total peak area’ for each of the volatiles listed. Ten volatile compounds corresponding to the 10 main peaks were identified in both soups and can be broadly categorized into five groups; limonene, p-cymene, terpinolene, β-caryophyllene, α-patcholene (Terpenes); dimethyl sulfide, isopropyl disulfide (Thioethers); 3,3-dimethyl hexane (Hydrocarbon); propanol-1 (Alcohol) and hexanal (Aldehyde). The headspace of both regular and reduced salt soups were dominated by terpene hydrocarbons, predominantly limonene, in addition to β-caryophyllene and p-cymene, however, a reduction to the salt content of the soup resulted in a much lower
The concentration of terpenes (29.13%) in comparison to the regular salt commercial soup (44.01%).

Table 5.10: Peak Areas (x 10^6) and Percentage of Total Area\(^1\) of Headspace Volatile Compounds Identified\(^2\) in Regular and Reduced Salt Vegetable Soup

<table>
<thead>
<tr>
<th>LRI(^1)</th>
<th>Compound Name(^2)</th>
<th>I.D.(^3)</th>
<th>Peak Area(^4)</th>
<th>% Total Area(^4)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Regular Salt</td>
<td>Reduced salt</td>
</tr>
<tr>
<td>677</td>
<td>A. Dimethyl sulfide</td>
<td>MS, LRI</td>
<td>0.19</td>
<td>0.76</td>
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<tr>
<td>810</td>
<td>B. 3,3-dimethyl hexane</td>
<td>MS, LRI</td>
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<td>1002</td>
<td>C. Propanol-1</td>
<td>MS, LRI</td>
<td>4.60</td>
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<td>1193</td>
<td>E. Limonene ***</td>
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<td>1273</td>
<td>F. (p)-Cymene ***</td>
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<td>G. Terpinolene</td>
<td>MS, LRI</td>
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<td>H. Isopropyl disulfide *</td>
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<td>1637</td>
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\(^1\) LRI = LinearRetentionIndex calculated on a ZB-wax column using \(C_8-C_{20}\)alkane mix. \(^2\) Compound name labels A. – J. correspond to the volatile labels in PLSR plot in Figure 5.9. \(^3\) I.D. = Peak identification: ST, comparison of spectra with authenticated standards; MS, tentatively identified by matching mass spectra with the data stored in the NIST library; LRI, retention index agrees with authenticated standards or published data (Machiels et al., 2003; Lubeck and Sutton, 1983; 1995; Choi, 2003). \(^4\) Data are the average of 4 measurements. Significant difference levels calculated by XLSTAT version 2010.5.01 software using paired t-tests where * ≤ 0.05, ** ≤ 0.01 and *** ≤ 0.005.

Limonene, the most abundant compound identified in both soups, was found in significantly different (p<0.005) concentrations with the regular salt soup containing over 3 times that of the reduced salt meal. \(\beta\)-caryophyllene and \(p\)-cymene, the third
and fourth most abundant compounds overall, and the second and third most abundant terpenes respectively, were identified in significantly different concentrations. The regular salt vegetable soup also had significantly higher concentrations of both β-caryophyllene (p<0.05) and p-cymene (p<0.005) in comparison with the levels present in the reduced salt soup. These 3 terpene hydrocarbons have been previously identified in carrots (Alasalvar et al., 1999; Varming et al., 2004; Ibrahim et al., 2006; Soria et al., 2008) and it is therefore, of no surprise that they are the most predominant terpenes within the soup given the high concentration of carrots in the formulation. Kjeldsen et al. (2003) reported that all 3 of these terpene hydrocarbons had odour sensations in carrots, with limonene, the most predominant compound identified in the present study, having an odour threshold value (OTV) of ~200ppb in water. β-caryophyllene was found to have an OTV of ~160ppb while P-cymene, the least abundant of these 3 terpenes identified in the present study, appeared to have the strongest impact on odour with an OTV of 13ppb (Kjeldsen et al., 2003). Limonene, the most abundant compound identified in both soups, has also previously been identified in other vegetable soup ingredients including potato (Oruna-Concha et al., 2002), turnip (Taveira et al., 2009), celery (MacLeod et al., 2010), butter (Povola and Contarini, 2003) and white pepper (Plessi et al., 2002). However, despite limonene being present in high amounts in the soup, it appears not to be as important to the overall flavour and aroma of the soup as some of the other terpenes which were present in smaller amounts, a finding which is supported by Coulttate (1999).

Other terpenes identified in both vegetable soups included terpinolene, which was at a slightly higher concentration in the regular salt soup and α-patchoulene, which was almost double the concentration in the reduced salt soup in comparison to the regular salt soup, however, it must be noted that these were present in relatively low amounts. Terpinolene, the more widely reported of these 2 terpenes, has been previously identified in both carrots and white pepper (Alasalvar et al., 1999; Plessi et al., 2002; Varming et al., 2004; Ibrahim et al., 2006; Soria et al., 2008). Kjeldsen et al. (2003) reported that this monoterpane had an OTV of 200ppb in water and determined this compound to be the ‘most important’ with regards aroma sensation in carrots. Alpha-patchoulene, generally associated with the essential oil of patchouli, a bushy herb from the mint family and a popular ingredient in the perfume industry (Aruldass, 2010), is not often found in vegetables. However, it is often used as a
natural additive in food flavourings (Donelian et al., 2009) and has been identified in basil oil (Tsai and Sheen, 1987) and virgin olive oil (Haddada et al., 2007).

Isopropyl disulfide, which is synonymous with bis(1-methylethyl) disulfide, was the second most abundant volatile compound identified in both soups and was found in significantly higher (p<0.05) concentrations in the regular salt soup. This compound together with the other sulfide volatile identified, dimethyl sulfide, can be largely attributed to onions present in the soup formulation. Prithiviraji et al. (2004) identified bis(1-methylethyl) disulfide in onion bulbs, while Povolo and Contarini (2003) and Oruna-Concha et al. (2002) identified dimethyl sulfide in butter and potato respectively. Similar sulfide volatiles have also been identified in onion and turnip (Boelans et al., 1971; Kallio and Salorinne, 1990; Taveira et al., 2009). Duckham et al., (2001) reported the OTV’s of dimethyl trisulfide to be equal to 0.01ppb and dimethyl disulfide to be 0.2ppb in baked potatoes. In another study, Boelens et al., (1971) determined the OTV of dipropyl disulfide in onions to be 3.2µg/l in water. Although these compounds are not identical to either of the sulfide compounds identified in the present study, their low OTV are an indication of the importance of sulfide compounds on the aroma of foods.

Hexanal, the only aldehyde identified in the soups, was found in slightly higher concentrations in the regular salt vegetable soup, however, its levels overall were low ranging from 1.23 (peak area x 10^6) in the reduced salt soup to 1.51 (peak area x 10^6) in the regular salt vegetable soup. Hexanal has previously been identified by several authors in ingredients such as dehydrated carrot (Soria et al., 2008), turnip (Taveira et al., 2009), celery (MacLeod et al., 1988), butter (Povola and Contarini, 2003), vegetable oil (Stashenko et al., 1997) and potato (Petersen et al., 1998; Longbardi et al., 2011). In a study on baked potatoes Duckham et al. (2001) reported the OTV of hexanal as 4.5ppb. Kalua et al. (2007) conducted a review of olive oil volatile compounds and reported previously determined OTV’s ranging from 75-300µg/kg in oil. In this study, propanol-1 and 3,3-dimethyl hexane were both found in higher concentrations in the regular salt soup.

Overall, reducing the level of salt in a vegetable soup ready-meal resulted in a lower concentration of volatiles being released into the headspace. A reduction of
52% in the levels of salt added to the meal resulted in a 50% decrease in total volatiles. These results show that the ‘salting-out’ phenomenon is applicable to complex foods such as a vegetable soup where a total of 8 out of the 10 volatiles identified were found in higher concentrations in the regular salt vegetable soup. The lower level of terpenes present in the reduced salt soup may explain the weaker ‘carrot aroma’ associated with this soup.

While analysis of volatile composition using GC-MS is of value in measuring the chemical flavour composition of foods, the technique has a number of limitations that can make it difficult to relate measurements to sensory analysis by a trained panel. For example, in the present study SPME was used to sample the headspace of reduced and full salt ready-meals. Quantification using this method of analysis relies on headspace volatiles reaching equilibration between the foodstuff, the headspace and the SPME fibre. In the present study while an initial evaluation of the equilibration time required was carried out based on total volatile concentration, the sampling conditions used may not be ideal for all volatiles quantified. In addition, in the present study the most abundant volatiles present in the headspace were quantified and their concentration correlated by PLSR with sensory profile descriptors. The most abundant volatiles are not necessarily a reflection of the sensory properties of a foodstuff as components with low odour thresholds may be present at low concentrations and would therefore, have not been measured in the present case. CHARM or aroma extract dilution analysis would likely be required to pinpoint volatiles with the greatest contribution to the final flavour profile. Given the complexity of the foods analysed in this case, this type of analysis was deemed outside the scope of the present work.

**5.4.4 Correlation of Sensory Profiling Data with Volatile Analysis Data**

Figures 5.7, 5.8 and 5.9 show the partial least squares regression (PLSR) correlation loading plots for all flavour and aroma sensory attributes and volatile compounds generated using the XLSTAT software for cottage pie, chicken supreme and vegetable soup, respectively. In each case the chemical data set were assigned as the X-variables or independent variables and the sensory attributes were assigned as the Y-
variables or dependant variables under the assumption that the sensory perception of each ready-meal was affected and dependant upon its volatile flavour profile.

5.4.4.1 Cottage Pie

The PLSR correlation loading plot in Figure 5.7 explained 65.87% of the variance. An assessment of the data revealed several correlations between the sensory data and volatile compounds. Methyl allyl sulfide (C) was positively correlated with “beef flavour” (0.85) and “sweet flavour” (0.74). These sensory attributes received almost identical scores in both the regular and reduced salt meals during sensory profiling (Figure 5.1) and similarly during volatile analysis, methyl allyl sulfide (C) was found in comparable amounts in both meals (Table 5.8), therefore, no concrete conclusions on the effects of these compounds on the flavour and aroma of the meals can be drawn from these correlations. Hexanal (E), one of 2 aldehydes identified in the cottage pie, was found to be positively correlated with the sensory attribute “butter flavour” (0.64) and negatively correlated with “pepper flavour” (-0.78). Based on these correlations the larger abundance of hexanal (E) in the reduced salt cottage pie resulted in a decreased “pepper flavour”. However, the increased concentration of hexanal in the reduced salt meal had no effect on the sensory attribute “butter flavour” which received similar scores in both the regular and reduced salt meals during sensory profiling (Figure 5.1). The second aldehyde identified in the ready-meal was 2-undecenal (J), a compound which was positively correlated with the sensory attributes “salt flavour” (0.93) and “oily aroma” (0.88), both of which received significantly higher intensity scores in the regular salt ready-meal (Figure 5.1). 2-Undecenal is a product of lipid oxidation and its greater abundance in the regular salt meals may be derived from the fact that salt is a known pro-oxidant (Torres et al., 1988), therefore, its correlation with “oily aroma” is no surprise. 2-Undecenal (J) was negatively correlated with several sensory attributes previously found to be significantly higher in the reduced salt cottage pie (Figure 5.1) namely “persistent aftertaste” (-0.87), “oily flavour” (-0.83) and “aftertaste” (-0.81). Therefore, the decreased level of this compound in the reduced salt meal can be linked with the increased ‘aftertaste’ associated with this reduced salt meal.
Figure 5.7: PLSR Correlation Loading Plot of the Relationship between Volatile Measurements (X-Variables) and Sensory Attributes (Y-Variables) in Cottage Pie Ready-Meals

Diallyl sulfide (F) on the other hand was positively correlated with the reduced salt sensory attribute “persistent aftertaste” (0.73), “uneven surface colour” (0.71) and negatively correlated with the regular salt sensory attributes of “pepper flavour” (-0.89). Limonene (G), p-cymene (H) and β-caryophyllene (I) showed moderate correlations with a small number of the sensory attributes. P-Cymene (H), a volatile identified in similar amounts in both the regular and reduced salt meals, was positively correlated with “beef flavour” (0.71). β-Caryophyllene (I) showed positive correlations with “beef flavour” (0.68), “sweet flavour” (0.63) and “oily aroma” (0.64), of which only “oily aroma” was found to be significantly different during sensory profiling (p<0.05; Figure 5.1). Limonene (G), the most abundant compound identified in the reduced salt ready-meal, was found to be positively correlated with
“potato flavour” (0.83) and “aftertaste” (0.67). Of these two sensory attributes “aftertaste” was the only one found to be significantly higher in the reduced salt meal (Figure 5.1), therefore, the higher presence of limonene in the reduced salt meal can be associated with this meal having a greater aftertaste.

5.4.4.2 Chicken Supreme

In total, the PLSR correlation loading plot in Figure 5.8 explained 80.56% of the variance. From Figure 5.8 we can see a cluster of sensory attributes namely “oily aroma”, “wine flavour”, “mushroom flavour” and “salt flavour” which appear highly correlated with the volatile piperidine (G). Upon closer inspection of the data the heterocyclic amine piperidine (G), which was present in a significantly higher concentration in the regular salt soup (p<0.05; Table 5.9), was found to be highly correlated with “oily aroma” (0.91), “salt flavour” (0.90), “wine flavour” (0.88) and “mushroom flavour” (0.85). Therefore, as the level of piperidine in the chicken supreme ready-meal increased the intensity ratings for the above listed sensory attributes also increased. These sensory attributes all received higher intensity scores in the regular salt meal, several of which were found to be significantly different during sensory profiling (Figure 5.3). Several volatiles namely ethyl acetate (C), ethanol (D), pentan-2-one (E), α-pinene (F), 2-pentylfuran (K), methyl pyrazine (L) and β-caryophyllene (N) were found to be positively correlated with the reduced salt chicken supreme attribute “sweet flavour”. All of these 7 volatile compounds, with the exception of methyl pyrazine (L), were present in a higher concentration in the reduced salt ready-meal. Comuzzo et al., (2006) reported ethanol and 2-methylpyrazine to have sweet odour. Mussinan et al. (1980) found that a caryophyllene alcohol mixture had a sweet aroma and sweet flavour topnotes. Diallyl sulfide (I) was also found to be positively correlated with “sweet flavour” (0.69), however, this correlation was not as strong as those associated with the above list of volatiles (C, D, E, F, K, L and N).
Limonene (J), a compound which was present in a significantly higher concentration (p<0.05) in the reduced salt ready-meal, was positively correlated with “cream flavour” (0.67). Limonene has previously been identified in several dairy products including heated milk (Valero et al., 1999), skimmed milk powder (Shiratsuchi et al., 1994) and butter (Povolo and Contarini, 2003) and its presence in these dairy based products may explain its correlation with “cream flavour”. Hexanal (H), the most abundant compound identified in both the regular and reduced salt meals, was found to be positively correlated with the sensory attributes “salt flavour” (0.66), “wine flavour” (0.66) and “dairy aroma” (0.65) and negatively correlated with the sensory attribute “sweet flavour” (-0.75). Hexanal’s (H) positive correlations with the above listed sensory attributes can be easily understood as both the level of hexanal and the sensory scores for these attributes were all high in the regular salt meal. However, the
negative correlation associated with hexanal is not as easily understood as the level of hexanal and the sensory scores for “sweet flavour” were all high in the reduced salt meal, and not opposite i.e. one high and the other low or vice-versa, as a negative correlation would suggest. The volatile dimethyl trisulfide (M) was found to be positively correlated with the sensory attribute “onion flavour” (0.64). Sulfide compounds make up a large proportion of the aroma volatiles identified in onions (Rowe, 1998) and it is therefore, of no surprise that dimethyl trisulfide was correlated with “onion flavour”. Indeed the compound itself has previously been identified in onions by Boelens et al. (1971) and Kallio and Salorinne (1990).

5.4.4.3 Vegetable Soup
In total, the PLSR plot explained 75.37% of the variance. From Figure 5.9 it is evident that a clustering of sensory attributes are present namely, “overall flavour”, “aftertaste”, “yellow colour”, “salt flavour”, “overall flavour complexity” and “carrot aroma” appear well correlated with the volatiles propanol-1 (C), hexanal (D), limonene (E), p-cymene (F), isopropyl disulfide (H), β-caryophellene (I). Upon closer inspection, the cyclic terpene limonene (E), the most abundant volatile in both soups and which was present in significantly higher concentrations in the regular salt soup (p<0.005; Table 5.10), was found to be highly correlated with “salt flavour” (0.97), “yellow colour” (0.93), “carrot aroma” (0.92), “overall flavour” (0.86), “overall flavour complexity” (0.85) and “aftertaste” (0.82). These sensory attributes all received higher intensity scores in the regular salt meal, several of which were found to be significantly different, during sensory profiling (Figure 5.3). This volatile compound was also found to be negatively correlated with “sweet flavour” (-0.91), “green colour” (-0.88) and “pepper flavour” (-0.81); sensory attributes associated with the reduced salt soup. Almost identical correlations with the above listed sensory attributes, both positive and negative, were observed for the volatiles propanol-1 (C), p-cymene (F), isopropyl disulfide (H) and β-caryophellene (I). Hexanal (D) on the other hand was found to be positively correlated with the same attributes above i.e. “salt flavour” (0.75), “yellow colour” (0.83), “carrot aroma” (0.81), “overall flavour” (0.83), “overall flavour complexity” (0.69) and “aftertaste” (0.70), however, these correlations were not as strong as the above mentioned volatiles. No negative correlations were observed for this volatile.
Figure 5.9: PLSR Correlation Loading Plot of the Relationship between Volatile Measurements (X-Variables) and Sensory Attributes (Y-Variables) in Vegetable Soup Ready-Meals

A–J corresponds to the ten volatiles identified and listed in Table 5.10. Abbreviations correspond to descriptive attributes listed in Table 5.5.

Therefore, the presence of the above named volatiles in the vegetable soup appear important to the flavour profile of the regular salt meal as apparent by the positive correlations between these volatiles and the regular salt soup sensory attributes. The negative correlations between these volatiles and the reduced salt attributes of “sweet flavour”, “green colour”, and “pepper flavour” further reinforce the importance of these volatiles on the flavour and aroma of the regular salt vegetable soup. As these negative correlations suggest an increase in the levels of propanol-1, limonene, p-cymene, isopropyl disulfide and β-caryophyllene decrease the intensity of the reduced salt sensory attributes and vice versa. Previous studies have found limonene, the most abundant compound identified in both meals, to be positively correlated with “carrot aftertaste” (Varming et al., 2004), while p-cymene has been reported to be an
important contributor to the characteristic “carrot-top” aroma in carrots (Kjeldsen et al., 2003). Beta-caryophyllene has previously been associated with a perfumery note in carrots and with “spicy”, “woody” and “sweet notes” (Alasalvar et al., 1999; Kjeldsen et al., 2003). Although no direct comparisons can be made between these findings and the current study due to different experiment designs, the presence of these volatiles in the vegetable soup and the similarity between their associated characteristic aroma notes and the current study’s sensory attributes is potentially more than a mere coincidence.

In Figure 5.9 the volatile 3,3-dimethyl hexane (B) does not appear to be closely correlated with any of the sensory attributes, however, upon closer inspection of the data 3,3-dimethyl hexane (B) was found to be positively correlated with “overall flavour” (0.79) and “salt flavour” (0.73) and negatively correlated with “green colour” (-0.75) and “sweet flavour” (-0.71). A positive correlation (0.76) was seen between the sesquiterpene α-patchoulene (J) and the sensory attribute “translucent appearance” and was found to be negatively correlated with the sensory attributes “yellow colour” (-0.71), “carrot aroma” (-0.75), “salt flavour” (-0.73) and “overall flavour complexity” (-0.69). From Figure 5.6 it can be seen that these attributes were associated with the regular salt soup. Therefore, as the level of α-patchoulene increased, one of the only volatiles identified that was present in a higher concentration in the reduced salt soup, the ratings for the above listed sensory attributes decreased, as was observed in the reduced salt soup. Its presence in the reduced salt soups volatile profile is undesirable due to the negative effect on the sensory attributes of the soup and its elimination from future formulations is a potential aim for food manufacturers. From Figure 5.9 we can see that dimethyl disulfide (A) was somewhat positively correlated with “sweet flavour” (0.57), “pepper flavour” (0.52) and “green colour” (0.50); sensory attributes which all received higher sensory scores in the reduced salt soup (Figure 5.5). Hence, as the level of dimethyl disulfide increased so too did the sensory ratings for these attributes. Although these are moderately weak correlations, it is interesting to note that dimethyl disulfide was present in a higher concentration in the reduced salt soup (Table 5.10). Terpinolene (G), despite being close to the sensory attribute “onion flavour” in Figure 5.9 was not correlated with it but was however, found to be negatively correlated with “surface oiliness” (-0.69). This sensory attribute was found to be very similar in both the
reduced and regular salt soups (Figure 5.5) and was also found in very similar concentrations during flavour volatile analysis (Table 5.10) and therefore, no concrete conclusions can be drawn from this correlation.

5.5 Conclusion
This combined instrumental and sensory approach could prove to be a valuable method of assessing the precise effect reformulation has on the flavour of complex food products like ready-meals, and may ultimately allow a more directed approach to overcome sensory deficits arising from salt reduction. Reduction of salt in the cottage pie had a significant impact on the attributes “uneven surface colour”, “oily flavour”, “oily surface shine” and “translucent appearance”. Sensory data for chicken supreme revealed that the attributes “sweet flavour” and “uneven surface colour” were significantly higher \((p<0.05)\) in the reduced salt ready-meal. While salt reduction in the vegetable soup had a significant effect \((p<0.05)\) on the sensory attributes “green colour”, “sweet flavour” and “pepper flavour”. SPME-GCMS analysis revealed a higher proportion of terpenes and aldehydes present in the headspace of both the reduced salt cottage pie and reduced salt chicken supreme ready-meals. In comparison, SPME-GCMS analysis revealed a ‘salting-out’ effect in the regular salt soup with significantly higher concentrations of terpenes and thioethers identified in comparison to its reduced salt counterpart. Partial least squares regression (PLSR) of the ready-meal data identified several significant positive relationships between volatile compounds identified and several sensory attributes associated with the regular salt ready-meals.
Chapter 6
6. The Use of Herbs, Spices and Whey Proteins as Natural Salt Substitutes and their Effect on the Sensory Acceptability of Reduced Salt Chilled Ready-Meals

6.1 Abstract
The use of herbs, spices and whey proteins as natural alternatives to salt substitutes in three reduced salt ready-meals was investigated. Individual addition of garlic, rosemary, oregano and sage at varying concentrations (0.1-0.5%) significantly (p<0.05) improved the acceptability of cottage pie, chicken supreme and vegetable soup ready-meals. However, both clove and pimento proved unacceptable individual additions to the ready-meals tested. Acceptability tests were then used to formulate spice blends for inclusion into all three ready-meals. These spice blends significantly increased the acceptability of cottage pie and chicken supreme ready-meals (p<0.05). However, the addition of spice blends into vegetable soup ready-meals is not recommended. Two lactoferrin whey proteins added at varying concentrations (0.1-0.5%) significantly increased mean acceptability (p<0.05) for each meal at all addition concentrations and demonstrated their potential as novel salt substitutes.
6.2 Introduction

Salt, or sodium chloride, is one of the most widely used food ingredients in the world today. Its popularity in food can be attributed to its varied functions in food; however, undoubtedly one of its more important roles in food is credited to its unique taste properties. Salt can also enhance and/or modify the flavour and tastes of other ingredients within a food (Hutton, 2002; Durack et al., 2008). However, evidence relating high salt consumption with high blood pressure has steadily increased over the past decade (Intersalt Cooperative Research Group, 1988; Law, 1997; FSAI Scientific Committee, 2005), resulting in health organizations worldwide requesting a reduction in the average population intake of sodium via a reduction of salt in processed foods (World Health Organization, 2003; SACN, 2003; FSAI Scientific Committee, 2005). Processed foods including soups, ready-meals and comminuted meat products are leading contributors to salt intake worldwide (Durack et al., 2008). The challenge currently faced by the food industry is to combine the convenience of processed products with more healthy low salt concentrations. The technical challenge is often related to the actual or perceived sensory impact salt reductions may have on a product or meal. The flavour of a product is a major influencing factor on an individual’s willingness to purchase a food or beverage. However, many consumers perceive low salt or sodium foods to be unpalatable, unpleasant, bland or even tasteless (Walsh, 2007). Therefore, maintaining the flavour of the original salted product is one of the key challenges facing the industry as they strive to formulate reduced salt foods (Bertino et al., 1981; Mitchell et al., 2011b). This is especially important in products such as ready-meals which are significant contributors to daily salt intakes (FSAI Scientific Committee, 2005) but which are also gaining popularity (particularly the chilled formats) as consumers have less time to prepare foods.

Food manufactures use two strategies to reduce salt concentrations in their products. The first approach involves incremental reductions in the amount of salt added to food formulations over an extended period until the desired low salt level is achieved. Evidence suggests that as the salt reductions are gradual the sensory attributes of the food appear unchanged to the consumer as their salt perception adjusts to the decreased salt level with time (Bertino et al., 1982). The second approach involves the immediate removal of salt present in the product with the resultant loss in salt taste being compensated for via changes in product formulation
to deliver the required flavour by other means. The use of non-sodium salts, flavour enhancers, bitter blockers and more recently dendritic or flake-type salts are common in the food industry. However, consumers are often wary of these additives and express a preference for more natural and nature-derived alternatives (Lomascolo, 1999; Paul, 2009). Herbs and spices have long been used throughout the world for their flavouring and aroma properties (Witkowska et al., 2011). In addition, recent evidence indicates that herbs and spices possess the ability to act as preservatives as well as providing added health benefits via their high levels of antioxidants (Tapsell et al., 2006). This has led to a renewed interest in these commodities as both sensory and functional additives. Whey proteins are also gaining popularity in recent years due to their health enhancing properties (Möller et al., 2008) and their increasing value as ingredients in functional food and beverages (Vardhanabhuti et al., 2010). However, whey proteins may also be associated with bitter (Hajirostamloo, 2010) and/or astringent (Vardhanabhuti et al., 2010) tastes. Therefore, fine tuning of the sensory properties of these ingredients when they are included in a food product is an essential step (Walsh, 2007) in low salt reformulation.

Traditionally, the impact of reformulation on the sensory properties of a food is determined via a series of sensory difference tests in combination with preference and consumer acceptability tests. We have previously investigated the impact of stepwise salt reduction on the sensory properties of frozen ready-meals and concluded that between 0.2 and 0.4% salt could be removed from a series of frozen ready-meals without sensory panellists detecting an effect in the taste properties of the meals (Chapter 4 & Mitchell et al., 2009a, 2009b and 2011b). In addition, further salt reductions between 0.4 and 0.6% could be achieved via the introduction of commercial salt replacers without sensory acceptability being affected. Therefore, the present study aimed to assess the usefulness of acceptability tests alone as a potential method to determine the effect of ingredients such as herbs, spices and whey proteins in three reduced salt chilled ready-meals. This involved determining the sensory acceptability and potential use as natural salt replacers of: (a) six herbs and spices, individually or in combination, and (b) two whey proteins, added into a selection of commercially produced reduced salt chilled ready-meals.
6.3 Materials and Methods

6.3.1 Ready-Meal Samples
Three popular commercially available freeze-chilled ready-meals were selected for inclusion in this study. These ready-meals included a chicken supreme - a chicken and mushroom dish in a cream and wine sauce; a cottage pie - a savory minced beef dish topped with potato; and a chunky vegetable soup. Two 500kg batches of each ready-meal type were manufactured by Dawn Fresh Foods Ltd., Fethard, Co. Tipperary, Ireland, according to their standard industrial protocols. A complete list of ingredients used in the manufacture of each ready-meal is listed in Table 5.1 (page 107). One batch of each ready-meal was formulated to contain regular commercial levels of sodium whereas the second batch was reformulated to contain significantly reduced sodium levels. These levels are detailed in Table 5.2 (page 108). Samples were pre-packaged in 250g – 300g portions and stored at -18°C upon receipt.

6.3.2 Addition of Individual Herbs, Spices and Whey Proteins
Six different powdered herbs and spices including oregano, sage, rosemary, garlic, pimento and clove (AllinAll Ingredients Ltd., Dublin 12) were selected for inclusion in the present study based on their sensory properties, antioxidant activity (Hossain et al., 2008) and potential as antimicrobial agents (Witkowska, et al., 2011). The day before sensory evaluation, regular and reduced salt ready-meals were removed from the freezer and thawed overnight at 4°C. Four concentrations, 0.5%, 0.25%, 0.15% and 0.1% (w/w), of each of the six herbs and spices were added into the three reduced salt ready-meals. In the case of the chicken supreme and vegetable soup meals this was achieved by direct addition of the spices into the meals which were then thoroughly mixed to ensure a homogeneous distribution of the added ingredients. In the case of the cottage pie ready-meals, the herbs and spices were only added to the savoury-minced beef and meat sauce layers of the meal and not the mashed potato layer. This was achieved by separating out the individual layers of each reduced salt cottage pie and placing the meat sauce layers from each meal into separate trays [110 x 150 x 60mm (Dynopak Ltd, Dublin)]. The contents of each tray were thoroughly mixed to ensure a homogeneous distribution of spice and then re-assembled into their original trays. All meals were held at approximately 4°C for 1-2 hours prior to
sensory testing to ensure that the individual herb or spice had equilibrated fully throughout the meals.

6.3.3 Formulation and Addition of Herb and Spice Blends

The individual herbs and spices were mixed together to form several low salt spice blends unique to each of the three ready-meal types. The composition of these blends was determined by sensory acceptability data obtained during individual spice addition trials and resulted in a total of four herbs (oregano, sage, rosemary and garlic) being selected for both the chicken supreme and vegetable soup spice blends, and five spices (oregano, sage, rosemary, garlic and pimento) selected for addition to the cottage pie spice blends. Individual spices were then combined together in a ratio based on their most acceptable individual addition concentration i.e. 0.5, 0.25, 0.15 or 0.1%. For ease of use these concentration values were multiplied by 10 so that ratio values of 5, 2.5, 1.5 or 1 were used (see Table 6.1). For example, the first spice blend mixed for cottage pie ready-meals included 5 spices; garlic, rosemary, oregano, sage and pimento. These 5 spices were mixed together in the following ratio based on their most acceptable individual concentration: 1.5 garlic: 2.5 rosemary: 2.5 oregano: 2.5 sage: 1 pimento (Table 6.1). A total of five different spice blends were formulated for both the chicken supreme and vegetable soup ready-meals and a total of six spice blends were formulated for the cottage pie ready-meals (Table 6.1).

The day before sensory analysis, the required number of regular and reduced salt ready-meals were removed from the freezer and thawed overnight at 4°C. Based on the overall most acceptable individual spice concentration for each meal, it was decided that 0.1% (w/w) of each spice blend would be added into the chicken supreme and vegetable soup ready-meals and 0.25% (w/w) of each spice blend would be added into the cottage pie. Initial trials with the vegetable soup ready-meals revealed that addition of 0.1% of each spice blend was too concentrated and therefore, this addition figure was halved to 0.05% in all further trials. Spice blends were added into the reduced salt meals using the procedure outlined above for individual spice addition.
Table 6.1: Combination Ratios of the Individual Herbs and Spices Used in the Formulation of Spice Blends for Each Ready-Meal

<table>
<thead>
<tr>
<th>Blend Number</th>
<th>Spices Used</th>
<th>Ratio Used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cottage Pie Ready-Meal</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Garlic: Rosemary: Oregano: Sage: Pimento</td>
<td>1.5: 2.5: 2.5: 2.5: 1</td>
</tr>
<tr>
<td>2</td>
<td>Garlic: Rosemary: Oregano: Sage</td>
<td>1.5: 2.5: 2.5: 2.5</td>
</tr>
<tr>
<td>3</td>
<td>Garlic: Oregano: Sage: Pimento</td>
<td>1.5: 2.5: 2.5: 1</td>
</tr>
<tr>
<td>4</td>
<td>Garlic: Rosemary: Sage: Pimento</td>
<td>1.5: 2.5: 2.5: 1</td>
</tr>
<tr>
<td>5</td>
<td>Garlic: Rosemary: Oregano: Pimento</td>
<td>1.5: 2.5: 2.5: 1</td>
</tr>
<tr>
<td>6</td>
<td>Rosemary: Oregano: Sage: Pimento</td>
<td>2.5: 2.5: 2.5: 1</td>
</tr>
</tbody>
</table>

| **Chicken Supreme Ready-Meal**                            |                     |
| 1            | Garlic: Rosemary: Oregano: Sage                  | 2.5: 1.5: 1: 1      |
| 2            | Garlic: Rosemary: Oregano                        | 2.5: 1.5: 1         |
| 3            | Rosemary: Oregano: Sage                          | 1.5: 1: 1           |
| 4            | Garlic: Oregano: Sage                            | 2.5: 1: 1           |
| 5            | Garlic: Rosemary: Sage                           | 2.5: 1.5: 1         |

| **Vegetable Soup Ready-Meal**                             |                     |
| 1            | Garlic: Rosemary: Oregano: Sage                  | 1: 1.5: 1: 1        |
| 2            | Garlic: Rosemary: Oregano                        | 1: 1.5: 1           |
| 3            | Rosemary: Oregano: Sage                          | 1.5: 1: 1           |
| 4            | Garlic: Oregano: Sage                            | 1: 1: 1             |
| 5            | Garlic: Rosemary: Sage                           | 1: 1.5: 1           |

6.3.4 Addition of Whey Proteins

Two powdered whey proteins were supplied by colleagues at the University of Limerick including intact and hydrolysed lactoferrin. The day before sensory evaluation, a number of regular and reduced salt ready-meals were removed from the freezer and thawed overnight at 4°C. Four concentrations, 0.5%, 0.25%, 0.15% and 0.1% (w/w), of each whey protein was added into the three reduced salt ready-meals.
The whey proteins were added into the reduced salt meals using the procedure outlined above for individual spice addition.

6.3.5 Sensory Acceptability Test
The sensory acceptability of three ready-meal samples per session involved; one regular salt sample, one reduced salt sample and one reduced salt sample containing the various herbs, spices or whey proteins, being evaluated by sixty untrained consumers, all of whom were regular consumers of ready-meals. As the taste and flavour of a product is one of the most important determinants of consumer choice, a consumer acceptability test was used to ascertain consumer response to these salt substitutes/flavour enhancers. Consumers were recruited from staff and students of the AFRC and visiting personnel who ranged in age from 19 to 70 years of age. Each ready-meal type (i.e. chicken supreme, vegetable soup or cottage pie) was evaluated on a separate day with two sessions per spice concentration (n=30) being conducted. Additional acceptability tests were conducted with both the regular and reduced salt meals without the addition of spice to ascertain the acceptability of these meals. Analyses were conducted at the same time and on the same day each week. Consumers were asked to individually blind taste test each coded sample and rate their acceptability using the following 9 point hedonic scale; 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, 1 = dislike extremely.

For chicken supreme ready-meals, on each testing day approx. 500g of rice (Uncle Ben’s® Long Grain Rice, Mars Food Services, San Antonio, USA) and 1L of water were placed into a saucepan and cooked for 10 minutes or until all water had been absorbed. The cooked rice (approx. 10g) was placed into individual circular foil cases (50mm diameter). The chicken supreme meals were cooked for 7 minutes on full power in a microwave oven (850watt) and subsequently distributed evenly (approx. 33g) into the foil cases containing the rice. Vegetable soup ready-meals were individually cooked for approximately 7 minutes and cottage pie ready-meals were cooked for approximately 9 minutes on full power in a microwave oven (850watt) and subsequently distributed evenly into approximately 35g portions into circular foil cases (50mm diameter). All samples were served at approximately 72°C and were presented to panellists in a random order on white paper plates, labelled with three
digit random codes derived from the Compusense® five software (Compusense Inc., Ontario, Canada). Panellists were presented with samples in individual testing booths adjacent to the sample preparation area, equipped with serving windows, controlled lighting and computers for ballot presentation and data collection using Compusense® five software. Plastic cutlery, napkins and water to palate cleanse were also provided.

6.3.6 Data Collection and Statistical Data Analyses
Compusense® five software (Compusense Inc., Ontario, Canada), a computer software package for sensory analyses data collection was used during the course of this study. The software was used to create questionnaires, present questionnaires to panellists according to an experimental design plan and to collect and analyze all data. All statistical analyses were preformed using the Compusense® five software (Compusense Inc., Canada). Acceptability test data were analysed using crosstabulation, percentage crosstabulation and summary statistics (counts, medians, means and standard deviations). Paired t-tests were used to compare the acceptability of each individual spice, whey protein or spice blend with both the commercial regular salt meal and the reduced salt ready-meal. For each individual spice, whey protein and spice blend, analysis of variance (ANOVA) was applied to determine concentration effects. Tukey’s HSD was applied to those found significant by ANOVA to determine which mean acceptability scores were significantly different from one another.

6.4 Results and Discussion

6.4.1 Effect of Salt Reduction on the Acceptability of Commercial Ready-Meals
Results from acceptability tests carried out on all regular or reduced salt ready-meals without the addition of herbs, spices or whey proteins are presented in Figure 6.1. Reducing salt levels in all three ready-meal types had the effect of reducing mean acceptability scores compared with meals containing regular salt levels. However, this reduction in acceptability scores was only significant for cottage pie ready-meals (p<0.005). Regular or reduced salt variants of chicken supreme or vegetable soup
ready-meals showed no significant difference in mean acceptability scores (p>0.05). In contrast to the cottage pie, the chicken supreme ready-meal which is also a processed meat product, showed no significant difference in mean acceptability scores between the reduced or regular salt variants. The level of salt removed from this meal was less than half the amount removed from the cottage pie (0.22% in chicken supreme against 0.45% removed in cottage pie) and this low level of salt removal did not appear to affect sensory properties of the meal. In fact, earlier work conducted on chicken curry ready-meals showed that salt reductions of this magnitude (~0.2%) could be achieved without sensory panellists noticing a difference in the overall taste and salty taste of the meals (Chapter 4). This would also imply that there should be no significant affect on acceptability scores as was observed in the present study.

Figure 6.1: Mean Acceptability Scores\(^1\) for All Regular and Reduced Salt Ready-Meals

![Figure 6.1](image)

\(^1\) Mean acceptability score of 60 consumers ± SEM. Bold black line = limit of acceptability. Within each ready-meal type different letters indicate significantly different samples; calculated using paired t-tests.
6.4.2 Effect of Individual Herbs and Spices on the Acceptability of Reduced Salt Ready-Meals

6.4.2.1 Cottage Pie
Mean acceptability scores for the four different concentrations of individual spices incorporated into the cottage pie ready-meal are presented in Figure 6.2. No significant difference (p>0.05) between acceptability scores was observed for the four addition concentrations for garlic or rosemary. While not significant, garlic added at a concentration of 0.15%, had the highest acceptability, while a concentration of 0.25% was found the most acceptable for rosemary. Mean acceptability scores for all four concentrations of garlic or rosemary were higher than those received for the reduced salt ready-meal which had a mean acceptability score of 6.7 (Figure 6.1) however, these acceptability scores were not significantly higher (p>0.05). The addition of oregano at the highest level (0.5%) significantly reduced acceptability scores (p<0.05) in comparison to lower addition levels. In fact, the acceptability score of 5.6 for the addition of 0.5% oregano was close to the limit of acceptability, and therefore, the use of 0.5% oregano is not recommended. Similar to results for rosemary and oregano, the addition of sage at a concentration of 0.25% was found to be the most acceptable. The mean acceptability score for the addition of 0.25% or 0.15% sage was significantly higher than that of the regular salt ready-meal at 8.1 (p<0.05). The use of pimento in the cottage pie ready-meals should also be avoided as even at 0.15% as this resulted in a mean acceptability of 4.9, a score below the cut off point of 5.0. As a consequence the higher addition concentrations for pimento of 0.25% or 0.5% were not presented to consumers for acceptability testing as we believed that an increase in pimento concentration would further decrease the acceptability score. Clove was included in the present study as it is both a strong antimicrobial and antioxidant agent (Witkowska et al., 2011; Hossain et al., 2008). However, when incorporated into the reduced salt ready-meal even at the lowest concentration i.e. 0.1%, it was found to be unacceptable and received the lowest mean acceptability score (3.6) of all spices and addition concentrations incorporated into the cottage pie. Due to the low mean acceptability score associated with clove addition at the lowest level, all other higher concentration levels were not tested.
Figure 6.2: Mean Acceptability Scores\(^1\) for Reduced Salt Cottage Pie Ready-Meals with Added Individual Herbs and Spices at Four Different Concentrations

\[^1\] Mean acceptability score of 60 consumers ± SEM. Bold black line = limit of acceptability. Within each herb or spice different letters indicate significantly different samples, calculated by Tukey’s HSD.

In summary, the individual addition of 0.25% rosemary, oregano and sage or 0.15% of garlic generally increased consumer acceptability scores in line with the commercial regular salt cottage pie. These individual levels of herbs and spices were selected for further examination in blend formats.

6.4.2.2 Chicken Supreme

Results of individual spice addition on the acceptability of reduced salt chicken supreme ready-meals are presented in Figure 6.3. No significant difference (p>0.05) in mean acceptability scores were found between 0.25%, 0.15% or 0.5% garlic additions. However, 0.25% garlic addition was found to be significantly more acceptable (p<0.05) than 0.1% garlic. No significant difference (p>0.05) was observed between the addition of rosemary at levels of 0.1%, 0.15% or 0.25%. However, addition of 0.5% rosemary was found to be significantly less acceptable (p<0.005) than the three lower addition concentrations resulting in a mean acceptability score of 3.7. As a consequence, the addition of 0.5% rosemary in a reduced salt chicken supreme is not recommended. No significant difference (p>0.05) was observed between 0.1%, 0.15% or 0.25% oregano with mean acceptability scores ranging from 7.0 to 6.0. A significantly (p<0.01) higher level of
acceptability was observed between these three addition levels and 0.5% oregano, which received a mean acceptability score of 4.5, a score below the limit of acceptability. Therefore, the addition of oregano at a concentration of 0.5% into a chicken supreme ready-meal is not advised. Sage at a level of 0.1% received a mean acceptability score of 8.2, a score well in excess of the regular salt meals mean score of 6.2. Both 0.15% and 0.25% sage also had mean acceptability scores above that of the regular salt meal. However, significant differences (p<0.01) were observed between 0.1% or 0.25% sage addition. Despite this 0.1%, 0.15% or 0.25% levels all received significantly higher (p<0.005) mean acceptability scores than the addition of 0.5% of sage. Addition of 0.5% sage resulted in a mean score of 5.1, which is just above the cut-off point of acceptability with a score below that of the reduced salt ready-meal. Therefore, its use is not recommended in a reduced salt chicken supreme. The addition of 0.1% of both pimento and clove into the reduced salt chicken supreme resulted in extremely low mean acceptability scores equivalent to 3.8 and 2.6, respectively. Due to the low scores received by both these spices at these levels any higher concentrations were not further evaluated.

**Figure 6.3:** Mean Acceptability Scores\(^1\) for Reduced Salt Chicken Supreme Ready-Meals with Added Individual Herbs and Spices at Four Different Concentrations

\(^1\) Mean acceptability score of 60 consumers ± SEM. Bold black line = limit of acceptability. Within each herb or spice different letters indicate significantly different samples, calculated by Tukey’s HSD.
In summary, the individual addition of 0.1% garlic, oregano and sage or the addition of 0.15% rosemary into a reduced salt chicken supreme resulted in mean acceptability scores which exceed those of the commercial regular salted product. Addition of 0.1% pimento or clove in addition to 0.5% of rosemary, oregano or sage resulted in unacceptable sensory scores. Therefore, their addition would not be recommended either individually or in combination with other spices for use in a reduced salt version of this particular meal.

Figure 6.4: Mean Acceptability Scores for Reduced Salt Vegetable Soup Ready-Meals with Added Individual Herbs and Spices at Four Different Concentrations

6.4.2.3 Vegetable Soup
Results of acceptability tests conducted on reduced salt vegetable soup with added individual herbs and spices are presented in Figure 6.4. Similar to previous ready-meal trials, the addition of 0.1% of either clove or pimento into the reduced salt soup resulted in unacceptable sensory scores. Addition of 0.25% sage resulted in a mean score which was classified as unacceptable; therefore, 0.5% sage was not added into the vegetable soup. Incorporation of 0.1% sage was found to be the most acceptable with mean scores matching those of the full salt commercial soup. Addition of 0.15% sage resulted in a mean acceptability scores of 6.2, which although acceptable were below those received by the reduced salt soup. All three addition levels were found to
be significantly different from each another (p<0.01). The addition of both garlic and oregano into the reduced salt vegetable soup resulted in very similar mean acceptability scores. An inverse relationship was found between increasing addition levels of both spices and acceptability scores for these meals. Addition at 0.5% of both spices resulted in unacceptable sensory scores of 4.2 and 4.1, respectively, with positive error bars for both spices also below the limit of acceptability. The addition of 0.25% of either spice was considerably less acceptable than the reduced salt ready-meal. Considering that negative error bars associated with both these spices were close to the limit of acceptability their use in future formulations at this concentration would not be advised. Significant differences (p<0.005) in mean acceptability scores were observed for both spices between addition levels of 0.5%, 0.25% and addition levels of 0.1% or 0.15%. However, no significant difference (p>0.05) was noted for either spice between addition levels of 0.1% and 0.15%. Of these lower addition levels, 0.1% was found to be the most acceptable with mean scores comparable with those of the commercial regular salt vegetable soup. Addition of rosemary resulted in no significant difference (p>0.05) in mean acceptability scores at 0.1%, 0.15% or 0.25% addition levels. However, the addition of 0.5% rosemary resulted in significantly less acceptable (p<0.005) sensory scores than those received at the other three addition levels.

In general, the addition of 0.5% of each spice resulted in acceptability scores well below the limit of acceptability. Similar to previous work with chicken supreme, the addition of 0.1% pimento or clove resulted in unacceptable sensory scores and therefore, their inclusion into a reduced salt vegetable soup would not be recommended. However, the addition of 0.1% garlic, oregano or sage and the addition of 0.15% rosemary resulted in sensory scores comparable with the regular salt commercial vegetable soup.
6.4.3 Effect of Spice Blend Addition on the Acceptability of Reduced Salt Ready-Meals

6.4.3.1 Cottage Pie

The individual spice concentrations selected for use in the formulation of the cottage pie spice blends were; 0.15% garlic, 0.25% rosemary, oregano and sage and 0.1% pimento. A total of 6 blends were subsequently formulated using these spices for the cottage pie ready-meal (Table 6.1). As 0.25% was found to be the most acceptable individual addition level for three out of the five spices (Figure 6.2) it was decided that 0.25% of each spice blend would be added into the reduced salt ready-meal.

![Figure 6.5: Mean Acceptability Scores for Reduced Salt Cottage Pie Ready-Meals with 0.25% Added Spice Blends](image)

Results from the addition of the various spice blends into reduced salt cottage pie are presented in Figure 6.5. Data indicated that all 6 spice blends and their corresponding error bars were above the limit of acceptability. In the case of spice blend 5, a significantly lower (p<0.05) mean acceptability score was observed. This blend contained a mixture of garlic, rosemary, oregano and pimento. In addition spice blend 5 was the only one that resulted in mean acceptability scores below that of the reduced salt ready-meal. No significant difference (p>0.05) was observed between

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1 Mean acceptability score of 60 consumers ± SEM. Bold black line = limit of acceptability. Within each herb or spice different letters indicate significantly different samples, calculated by Tukey’s HSD.
spice blends 1, 2, 3, 4 or 6 with blends 2, 3 and 6 receiving identical mean acceptability scores. Spice blend 1 which contained all five spices was the most acceptable with a mean score of 7.7. This particular blend was the only one which generated scores higher than those of the commercial regular salt cottage pie and therefore, its use as a potential salt substitute in the cottage pie ready-meal would be recommended.

**Figure 6.6: Mean Acceptability Score\(^1\) for Reduced Salt Chicken Supreme Ready-Meals with 0.1% Added Spice Blends**

![Bar chart showing mean acceptability scores for reduced salt chicken supreme ready-meals with 0.1% added spice blends.]

\(^1\) Mean acceptability score of 60 consumers ± SEM. Bold black line = limit of acceptability. Within each herb or spice different letters indicate significantly different samples, calculated by Tukey’s HSD.

### 6.4.3.2 Chicken Supreme

The individual spice concentrations selected for the chicken supreme spice blends were; 0.25% garlic, 0.15% rosemary and 0.1% oregano and sage. A total of 5 spice blends were formulated for the chicken supreme ready-meal based on these four spices (Table 6.1). As 0.1% was found to be the most acceptable addition level for two out of the four spices when added individually (Figure 6.3) it was decided to add each spice blend into the reduced salt ready-meal at this level.

Results from the addition of spice blends into the reduced salt chicken supreme meal revealed that all spice blends, with the exception of spice blend 2, received higher sensory scores than the commercial regular salt ready-meal (Figure...
However, it must be noted that spice blend 2, a mixture of garlic, rosemary and oregano, received a mean acceptability score similar to the commercial regular salt meal. The increased acceptability observed for the reduced salt ready-meals containing the various spice blends may be as a result of increased complexity within the meal. Malherbe et al. (2003) states that dish complexity plays an important role in acceptability, and reported that a decrease in acceptability was prevented in both reduced salt beef stew and reduced salt vegetable soup when there was a continuous perception of different tastes in the dishes, which masked the salt reduction. When food products are formulated to include ingredients with different taste properties, such as in complex dishes, salt elicits more than one taste quality (Malherbe et al., 2003). As chewing of a complex reduced salt food proceeds, partial adaption occurs due to the complexity of the food and contributes to the masking effect brought about by the other taste qualities present in the food (Kroeze, 1990). No significant difference (p>0.05) in mean acceptability scores was observed between blend 2 and blends 1 and 3 however, spice blend 2 was significantly less acceptable (p<0.05) than both spice blends 4 and 5. Of the five spice blends formulated and tested, spice blend 5, a mixture of garlic, rosemary and sage, received the highest acceptability score and therefore, its use as a potential salt substitute in reduced salt chicken supreme ready-meals would be recommended.

6.4.3.3 Vegetable Soup

The individual spice concentrations selected for use in the spice blends formulated for vegetable soup were; 0.1% garlic, oregano and sage and 0.15% rosemary. A total of 5 spice blends were formulated for the vegetable soup based on these four spices (Table 6.1). As 0.1% was found to be the most acceptable individual addition level for three of the four spices (Figure 6.4) it was decided to add 0.1% of each spice blend into the reduced salt ready-meal. However, initial sensory trials with 0.1% addition of each spice blend resulted in unacceptable mean sensory scores (data not shown) therefore, it was decided to add half this concentration at 0.05%. Data in Figure 6.7 refer to addition levels 0.05% of each spice blend.

From Figure 6.7 it is evident that there was no significant difference (p>0.05) in mean acceptability scores for either of the five spice blends formulated for the
reduced salt vegetable soup. Acceptability scores ranged from 6.7 for spice blend 1 up to 7.0 for spice blend 3. Spice blend 3, a mixture of rosemary, oregano and sage, received the highest acceptability scores of the five blends tested, however, these acceptability scores are equivalent to those of the control reduced salt vegetable soup. As the aim was to produce a spice blend which would act as a natural salt substitute, mean acceptability scores similar or higher than the regular salt ready-meal were the selection criteria. Therefore, the use of individual spices as opposed to the above mentioned spice blends may be recommended for use in a reduced salt vegetable soup.

Figure 6.7: Mean Acceptability Scores\(^1\) for Reduced Salt Vegetable Soup Ready-Meals with 0.05% Added Spice Blends

![Mean Acceptability Score Chart]

\(^1\) Mean acceptability score of 60 consumers ± SEM. Bold black line = limit of acceptability. Within each herb or spice different letters indicate significantly different samples, calculated by Tukey’s HSD.

Another viewpoint may be that the concentration at which each spice blend was added into the reduced salt vegetable soup i.e. 0.05% was too low to have an impact on the sensory acceptability of the soup and hence, the results presented in Figure 6.7 are similar to those of the reduced salt ready-meal in Figure 6.1. However, when 0.1% of each spice blend was added (data not shown) sensory acceptability was below the limit of acceptability, thus supporting the above statement that the use of individual spices as opposed to spice blends would be recommended for use in a reduced salt vegetable soup.
6.4.4 Effect of Whey Protein Addition on the Acceptability of Reduced Salt Ready-Meals

Results from the individual addition of two whey proteins into each ready-meal type are presented in Figure 6.8. From this figure we can see that the addition of both whey proteins increased the mean acceptability score of all reduced salt ready-meals comparable to their commercial regular salt counterparts (Figure 6.1). No significant concentration effect (p>0.05) was observed for either whey protein in any of the ready-meals. From Figure 6.8 it is evident that the addition of 0.25% or 0.5% intact lactoferrin and 0.15% lactoferrin hydrolysate into the cottage pie yielded the most acceptable results. For the chicken supreme meal the use of both whey proteins resulted in acceptability scores which were higher than those of the regular salt commercial meal, regardless of addition level. The incorporation of 0.5% of both intact lactoferrin and lactoferrin hydrolysate resulted in the most acceptable sensory scores for this meal. For the vegetable soup, addition of 0.1% intact lactoferrin resulted in a mean acceptability score of 7.3, while addition of 0.1% lactoferrin hydrolysate resulted in a mean acceptability score of 7.5.

Figure 6.8: Mean Acceptability Scores$^1$ for All Three Reduced Salt Ready-Meals with Whey Proteins Added at Four Different Concentrations

$^1$ Mean acceptability score of 60 consumers ± SEM. Bold black line = limit of acceptability. Within each whey protein for each individual ready-meal different letters indicate significantly different samples, calculated by Tukey’s HSD.
The addition of both whey proteins into all 3 ready-meals resulted in an increase in acceptability scores similar to their regular salt counterparts. Concerns over bitter or astringent tastes commonly associated with the use of several whey proteins were unfounded in the present study as no such consumer comments of these off-flavour were received during the sensory trials. In fact, reduced salt ready-meals containing the whey proteins received comments such as ‘nice savoury taste’ and ‘more flavoursome’ for example, which were similar to those obtained by the regular salt samples during testing. The focus on lactoferrin as a functional food ingredient has only gained momentum in recent years and consequently, to date very few studies have been carried out on the acceptability of lactoferrin whey proteins in processed food products. However, a recent study reported that the addition of 0.15% lactoferrin (w/w) into stirred yogurt products had no apparent effect on sensory properties (Palmano et al., 2011). The known link between proteins and enhanced umami taste (Halpern, 2000) in combination with the current findings implies that lactoferrin is a strong potential candidate as a new natural salt substitute.

6.5 Conclusion
The use of acceptability tests alone was shown to be an effective method of determining the impact new ingredients, such as herbs, spices and whey proteins, on consumer reaction and overall acceptability for three reduced salt ready-meals. These acceptability tests also proved to be a valuable tool in the formulation of several spice blends unique to each meal. The inclusion of herbs and spices as natural alternatives to salt replacements also proved promising. The individual inclusion of garlic (0.15%), rosemary (0.25%), oregano (0.25%) or sage (0.25%) and a spice blend consisting of garlic, rosemary, oregano, sage and pimento, resulted in reduced salt cottage pie receiving mean acceptability scores similar to its commercial regular salt counterpart. The addition of the individual spices garlic (0.25%), rosemary (0.15%), oregano (0.1%) and sage (0.1%) and a spice blend incorporating garlic, rosemary and sage, significantly improved the acceptability of reduced salt chicken supreme. In contrast, acceptability of the reduced salt vegetable soup was improved only via the addition of individual spices [garlic (0.1%), rosemary (0.15%), oregano (0.1%) or sage (0.1%)] with inclusion of spice blends having no effect on the sensory acceptability of the reduced salt ready-meal. The use of the whey protein lactoferrin
in both its intact and hydrolysed forms increased acceptability of all ready-meals at all addition concentrations and may to be a potential new natural alternative to current commercial salt substitutes.
Chapter 7
7. The Influence of Salt Taste Threshold on Acceptability and Purchase Intent of Reformulated Reduced Salt Vegetable Soups

7.1 Abstract
Evidence suggests a link between an individual’s salt taste sensitivity with their acceptability and consumption of salty foods. Individuals with a high salt intake appear to require a higher concentration of salt to obtain the same taste sensation as those less sensitive to salt. Therefore, in the present study the influence of salt taste threshold on the acceptability and subsequent purchase intent of a number of reformulated reduced salt vegetable soups was examined. Detection and recognition thresholds of salt taste in sixty consumers were measured via ingestion of a series of salt water solutions. The same sixty consumers then evaluated five vegetable soup samples, 4 of which had reduced salt concentrations (~0.45%) and one which had regular commercial salt concentrations (0.93%). A 9 point hedonic acceptability scale and a 5 point purchase intent scale were used to rate the samples. Individual detection and recognition thresholds had no significant effect (p>0.05) on consumer acceptability and purchase intent scores for any of the vegetable soup samples. The regular salt soup received the highest acceptability scores, however, reduced salt soups which had 0.15% rosemary or 0.1% lactoferrin hydrolysate added were the most liked reduced salt samples and received scores which were comparable with the regular salt soup. Vegetable soups which contained 0.05% of a spice blend of rosemary, oregano and sage, were found to significantly less acceptable (p<0.05) than these meals. Significant correlations were observed between vegetable soup acceptability scores and purchase intent ratings of the same samples (r=0.814; p=0.000). These results highlight the importance of both taste characteristics and the inclusion of the consumer in the reformulation process of reduced salt foods. The study also shows that salt reductions of up to 48% can be achieved in commercial vegetable soup without affecting consumers liking for the meal.
7.2 Introduction

Sodium chloride (NaCl) is the prototypical stimulus that elicits salty taste (McCaughey and Scott, 1998). The importance of sodium in human biology is reflected in the fact that only one taste quality is exclusively devoted to identifying foods containing sodium (McCaughey and Scott, 1998; Lucas et al., 2011). Sodium is an irreplaceable ion of the solute base of living organisms and without adequate levels life cannot be sustained (Leshem, 2009). It has been theorized that the evolutionary transition from sea to land required bodily cells to be surrounded by a salty solution comparable to sea water (Lucas et al., 2011). Our ancestors evolved in a hot, dry environment and survived primarily on herbivorous diets that were void of ionic sodium (Cirillo et al., 1994). Such conditions provoked a strong need for sodium conservation and consequently favoured the adaptation of complex physiological and behavioural strategies for ensuring an ocean-like environment for our cells (Morris et al., 2008). As a result, an appetitive response to sodium sources evolved to encourage the seeking out and intake of sodium sources (Morris et al., 2008; Lucas et al., 2011). Sodium appetite is the only proven innate behavioural mechanism for acquiring a specific nutrient molecule – other than thirst, its physiological Siamese twin (Fitzsimons, 1998; Leshem, 2009). It has been suggested that intake of sodium rich foods in excess of immediate bodily needs is a preventative mechanism serving to embed sodium sources in memory and thus ward off hyponatremic challenge (Leshem, 2009). However, while this may have applied to our ancestors, today much of the salt that individuals and manufacturers place in foods is present because people ‘like’ the taste of salty food better than the taste of the same food without salt (Bourne et al., 1993; Malherbe et al., 2003).

There is some evidence connecting an individual’s salt taste sensitivity with their liking and consumption of salty foods. Perceived salt intensity and acceptability of salty foods has been shown to be influenced by prior exposure to decreased or increased sodium concentration (Lucas et al., 2011). Bertino et al. (1982) found that the preferred levels of salt in food are dependant on the amount of salt consumed by individuals. When the concentration of sodium ions being consumed by an individual is constant, adaptation occurs and the salty taste sensation virtually disappears (Bartoshuk, 1978). To relict the salty taste, the concentration of sodium on the tongue must be increased (Bartoshuk, 1978). Individuals with a high salt intake appear to
require a higher salt concentration to obtain the same taste sensation as those less sensitive to salt (Durack et al., 2008). The perceived intensity of sodium chloride varies such that a specific concentration required to elicit weak saltiness in one individual may be strongly salty to another (Hayes et al., 2010). Therefore, the preferred level of salt in food depends on the levels of salt consumed, and it can be lowered by a reduction of dietary salt intake (Bertino et al., 1986; Beauchamp et al., 1990; Kim and Lee, 2009). Reducing sodium intake to 1600mg per day has been reported to increase perceived salt intensity and decrease liking of salty foods over time (Blais et al., 1986; Lucas et al., 2011).

The objective of this research was to establish if consumers salt taste threshold had an effect on the sensory acceptability of several reformulated reduced salt vegetable soups. This was achieved by measuring detection and recognition thresholds for salt in sixty individuals and subsequently, determining if these thresholds had an effect on sensory acceptability and purchase intent ratings.

7.3 Materials and Methods

7.3.1 Vegetable Soup Samples and Preparation
A popular commercially available freeze-chilled vegetable soup was selected for inclusion in the present study. Two separate 500kg batches of vegetable soup were manufactured by Dawn Fresh Foods Ltd., Fethard, Co. Tipperary, Ireland, according to their standard industrial protocol. A list of ingredients used to produce the soups is listed in Table 5.1 (page 107). One batch contained regular commercial levels of sodium (0.37% sodium; 0.93% salt equivalent) whereas the second batch was reformulated to contain significantly reduced sodium levels (0.18% sodium; 0.45% salt equivalent). Samples were pre-packaged in approximately 250g portions and stored at -18°C upon receipt.

Two-three days prior to sensory evaluation the required number of regular and reduced salt soups were removed from the freezer and tempered to chill at 4°C. Based on previous sensory results (Chapter 6), three different reduced salt formulations were
selected for inclusion in the present consumer acceptability trials. These three reduced salt formulations included, 1) reduced salt soups with 0.15% added rosemary, 2) reduced salt soups with 0.1% added lactoferrin hydrolysate, and 3) reduced salt soups with 0.05% of a spice blend containing 1.5 parts rosemary, 1 part oregano and 1 part sage (individual herbs/spices supplied by AllInAll Ingredients, Dublin 15; lactoferrin supplied by colleagues in the University of Limerick). These three reduced salt soup formulations were achieved by the individual addition of rosemary, lactoferrin or the herb/spice blend into soups which were subsequently thoroughly mixed to ensure a homogeneous distribution of spice. All meals were held at approximately 4°C for 1-2 hours prior to sensory testing to ensure that the added ingredients had equilibrated fully throughout the meals.

7.3.2 Sensory Analyses
Two separate sensory tests were conducted and varied in length from 5-15mins. Study 1 determined sensory panellists’ salt taste detection and recognition thresholds whereas study 2 determined sensory panellists’ acceptability and purchase intent of 5 soup samples, 4 of which had reduced salt contents. All salt taste threshold sensory analyses were fully completed and conducted prior to acceptability testing with soup samples. Sixty panellists (34 females, 26 males; aged between 22 and 56 years) were recruited from staff and students at the Teagasc Food Research Centre Ashtown, Dublin and all sixty panellists took part in both taste tests. All participants provided verbal consent prior to testing.

7.3.2.1 Salt Taste Threshold Measurements
The standard method for determining salt taste thresholds involves triangle testing with a series of salt water solutions, however, due to time constraints involved in the present project the method described by Lucas et al. (2011) was used to determine taste panellists salt taste thresholds. As a result every effort was made to reduce response bias. A series of eight sodium chloride solutions, 3, 4, 6, 8, 12, 17, 24 and 34mM, were prepared in accordance with standards set out by the International Standards Organisation (ISO 3972: 1991). Food grade anhydrous salt (Saxa, Premier Foods Inc., UK) and de-ionized water were used to make all 8 solutions. A 20ml
sample of each salt solution, labelled with a random 3-digit blinding code derived from the Compusense® five software, was served to each panellist at room temperature in order of increasing salt concentration. Taste panellists were unaware of the salt concentration presentation order and were simply requested to taste each sample from left to right i.e. from lowest salt concentration to the highest salt concentration. Panellists were asked to determine whether there was an absence of taste i.e. water like, a taste identified but unrecognizable i.e. detection threshold, or a taste quality that was fully recognized i.e. recognition threshold. Panellists were instructed to identify the taste present in a sample once they deemed it fully recognized, to ensure the correct identification of recognition threshold values. Recognition threshold was defined as the concentration at which the salty taste was correctly identified and the 2 subsequent solutions were also identified correctly (Lucas et al., 2011). Similarly detection threshold was defined as the concentration at which a taste quality was first identified but unrecognized and the 2 succeeding solutions were also identified as having an unrecognizable taste quality present. Participants who did not reach recognition threshold at a concentration of 34mM sodium chloride were asked to return on a separate day for retesting where three further salt solutions, 34, 45 and 60mM were served. Room temperature de-ionized water and unsalted crackers were provided for oral rinsing and palate cleansing between samples.

7.3.2.2 Consumer Acceptability Test

The sensory acceptability of five soup samples; one regular salt sample, one reduced salt sample and one reduced salt sample containing each of the three ingredients listed in section 7.3.1 above; were evaluated by sixty untrained consumers, all of whom were regular consumers of soup. Consumers were recruited from staff and students of the AFRC and visiting personnel who ranged in age from 22 to 56 years of age. Consumers were asked to individually blind taste test each coded sample and rate their acceptability using the following 9 point hedonic scale; 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, 1 = dislike extremely. Subsequently, consumers were asked how likely they were to purchase each soup sample using the following 5 point purchase intent scale; 5 = definitely buy, 4 =
probably buy, 3 = might or might not buy, 2 = probably not buy, 1 = definitely not buy. Vegetable soup ready-meals were individually cooked for approximately 7 minutes on full power in a microwave oven (850watt) and then distributed evenly into approximately 35g portions in circular foil cases (50mm diameter). All samples were served at approximately 72°C and were presented to panellists in a random order on white paper plates, labelled with three digit random codes derived from the Compusense® five software (Compusense Inc., Ontario, Canada). Panellists were presented with samples in individual testing booths adjacent to the sample preparation area, equipped with serving windows, controlled lighting and computers for ballot presentation and data collection using Compusense® five software. Plastic cutlery, napkins, water and non-salted crackers to palate cleanse were also provided.

7.3.3 Data Collection and Statistical Analyses

Compusense® five software (Compusense Inc., Ontario, Canada), a computer software package for sensory analyses data collection was used during the course of this study. The software was used to create questionnaires, present questionnaires to panellists according to an experimental design plan and to collect and analyze all data. All statistical analyses were preformed using the compusense® five software (Compusense Inc., Canada). Acceptability test and purchase intent data were analysed using crosstabulation, percentage crosstabulation and summary statistics (counts, medians, means and standard deviations). One-way analysis of variance (ANOVA) and Tukeys HSD were used to assess if there was a significant difference in acceptability scores and purchase intent ratings among the five samples. SPSS statistical software version 14.0 (SPSS Inc., Chicago, USA) was used to analyze salt taste threshold data and the values reported are the mean ± the standard error of the mean (SEM). SPSS software was also used to determine correlations between consumers salt taste thresholds, acceptability scores and purchase intent ratings of the five different soup samples.
7.4 Results and Discussion

7.4.1 Salt Detection and Recognition Thresholds
The mean salt detection threshold was established as $10.03 \pm 0.78$ mM and the mean salt recognition threshold was established as $22.23 \pm 1.27$ mM among consumers in the present study. These high values are outside the range of those previously reported and suggest that consumers in the present study have a high habitual intake of salt from their diets. Hatae et al. (2009) reported exceptionally low salt detection threshold values of $0.719$ mM and salt recognition threshold values of $9.68$ mM among a group of 40 females in Japan. While Lucas et al. (2011) found mean salt detection threshold values to equal $5.45$ mM and mean salt recognition threshold values of $19.30$ mM in a group of 56 participants (48 female, 8 male) in Australia. However, both of these previous studies relied heavily on data generated by female participants and research has shown that females typically have a lower dietary salt intake and thus, have lower detection and recognition thresholds than their male counterparts (Taguchi and Okamoto, 1990; Okoro et al., 1998). For example, Mitsuhashi et al. (2008) reported that salt detection threshold was lower in female students ($2.85$ mM) than in male students ($3.10$ mM). With this in mind the present study determined gender specific detection and recognition thresholds for salt. Salt detection thresholds were found to differ significantly ($p<0.05$) between male ($n=26$) and female ($n=34$) consumers with men having a mean salt detection threshold value of $11.88 \pm 1.54$ mM and women having a mean salt detection threshold of $8.71$ mM $\pm 0.69$ mM. Recognition thresholds were established as $24.76 \pm 2.24$ mM for men and $20.43 \pm 1.42$ mM for women. Despite female consumers having a lower salt recognition threshold in comparison to male consumers, no significant difference ($p>0.05$) was observed between the two genders. Therefore, the present study found that female consumers’ are more sensitive to the detection of salt taste in water solutions however, no gender differences were observed between male and female ability to fully recognize salty taste in water. This finding is similar to that of Mitsuhashi et al. (2008) who reported a significant difference between the genders in terms of salt detection threshold but found no difference between the genders in terms of recognition thresholds. Weiffenbach et al. (1982) and Kim and Lee (2009) also found no difference between the genders in terms of salt taste acuity.
7.4.2 Acceptability of Vegetable Soup Samples

When consuming a food in a relaxed or familiar setting, the acceptability of a dish is generally of greater importance than the perception of saltiness (Malherbe et al., 2003). Therefore, in the present study the acceptability of a number of reduced salt soups in comparison to commercial soups with regular salt levels was investigated. Results from the consumer acceptability test are presented in Figure 7.1. From this figure we can see that the regular salt vegetable soup was the most liked sample having received mean acceptability scores of 7.1. However, no significant difference (p>0.05) was found between this sample and three of the reduced salt ready-meals, namely the reduced salt soup alone (without added ingredients) and the reduced salt samples containing rosemary and lactoferrin. Of the four reduced salt samples, vegetable soups containing rosemary preformed the best with a mean acceptability score of 6.9. All five vegetable soup samples were above the limit of acceptability, however, the reduced salt samples containing a spice blend of rosemary, oregano and sage had a mean acceptability score which was close to this limit. These samples were found to be significantly less acceptable (p<0.05) than all other vegetable soup samples, with the exception of the reduced salt soup alone which did not contain any extra ingredients. The spice blend added soups, had mean acceptability scores which were lower than those received by the reduced salt samples alone (without added ingredients) and therefore, the use of a spice blend of rosemary, oregano and sage is not recommended for use in reduced salt vegetable soups. However, the addition of 0.15% rosemary or the addition of 0.1% lactoferrin hydrolysate are recommended as both ingredients increased acceptability scores up in line with the regular salted commercial meal. Addition of either ingredient into the reduced salt soups allowed for salt reductions of approximately 48% to be achieved without adversely affecting the sensory acceptability of the meals. However, if food manufacturers are to pursue this salt reduction strategy they may need to accept minor insignificant reductions in consumer acceptability as a result (Lucas et al., 2011).
Figure 7.1: Mean Acceptability Score\(^1\) of Regular and Reduced Salt Vegetable Soup Samples

![Chart showing mean acceptability scores for different soup samples]

\(^1\) Mean acceptability score of 60 consumers’ ± SEM. Bold black line = limit of acceptability. Different letters indicate significantly different samples, calculated by Tukey’s HSD.

7.4.3 Purchase Intent of Vegetable Soup Samples

Results from consumers’ intent to purchase the five vegetable soup previously tasted are presented in Figure 7.2. Results reveal that consumers intent to purchase both the reduced salt soup alone (without added ingredients) and the reduced salt soup containing a spice blend were below the purchase limit, meaning consumers would ‘probably not buy’ these samples. All other samples which included the regular salt soup, the reduced salt soup with added rosemary and the reduced salt soup with added lactoferrin, all had mean scores above the purchase limit, meaning consumer would ‘probably buy’ these samples. A significant difference (p<0.05) was found between consumers intent to purchase the regular salt soup and the soup with added spice blend, implying consumers were significantly more likely to purchase the regular salt soup over the reduced salt meal with added spice blend.
Figure 7.2: Mean Purchase Intent Score\(^1\) of Regular and Reduced Salt Vegetable Soup Samples

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Mean Purchase Intent Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular Salt</td>
<td>3.5 ± 0.2</td>
</tr>
<tr>
<td>Reduced Salt</td>
<td>3.0 ± 0.2</td>
</tr>
<tr>
<td>Rosemary Spice Blend</td>
<td>3.8 ± 0.2</td>
</tr>
<tr>
<td>Spice Blend</td>
<td>3.2 ± 0.2</td>
</tr>
<tr>
<td>Lactoferrin</td>
<td>4.0 ± 0.2</td>
</tr>
</tbody>
</table>

\(^1\) Mean acceptability score of 60 consumers' ± SEM. Bold black line = purchase limit. Different letters indicate significantly different samples, calculated by Tukey’s HSD.

7.4.4 Relationships between Salt Thresholds, Acceptability Scores and Purchase Intent Data

No significant correlations were observed between the salt detection threshold data and the vegetable soups acceptability scores (r=0.154; p=0.240). Similarly, no significant relationship was observed between the salt recognition threshold data and the acceptability of the vegetable soup ready-meals (r=0.105; p=0.424). Therefore, in the present study sensitivity to salt taste was not a factor in the acceptance and liking of regular and reduced salt vegetable soups. Lucas et al. (2011) reported similar findings following a study with hash browns and found oral sensitivity to salt taste in water solutions was not a factor in the liking of salty food. Several other studies suggest that salt recognition thresholds determined via sodium in solution are not correlated with intensity ratings in food (Bartoshuk, 1978; Beauchamp et al., 1990). Because much of the salt present in food today is ‘hidden’ within a food matrix, a set concentration of salt in two different foods may initiate widely different salt taste perceptions (Hayes et al., 2010; Lucas et al., 2011). Therefore, the sensitivity of consumers to salt taste in water will ultimately be different to their sensitivity to salt taste in a more complex food such as vegetable soup. It has been suggested that those
who consume high salt diets will have high salt taste thresholds as they are accustomed to the taste associated with elevated salt concentrations and thus, require more salt in their food before they deem it acceptable. Conversely, those who consume low salt diets will be much more sensitive to salt taste and will require lower levels of salt in food before they deem it acceptable. However, in the present study no significant correlations were found between those who had either high \( r=0.095; \ p=0.469 \) or low \( r=0.002; \ p=0.988 \) salt taste thresholds and the acceptability of vegetable soup samples. Similarly, differences observed between male and female consumers in terms of salt taste thresholds had no impact on acceptability scores \( M: \ r=0.146; \ p=0.266/ \ F: \ r=0.188; \ p=0.369 \) and purchase intent \( M: \ r=0.030; \ p=0.818/ \ F: \ r=0.154; \ p=0.240 \) ratings of vegetable soup ready-meals. Purchase intent scores were not correlated with salt taste detection thresholds \( r=0.073; \ p=0.581 \) and salt taste recognition thresholds \( r=0.095; \ p=0.471 \) and equally were not affected by high \( r=0.116; \ p=0.379 \) or low \( r=0.158; \ p=0.227 \) salt threshold concentrations. However, significant positive correlations were observed between vegetable soup acceptability scores and purchase intent ratings of the same samples \( r=0.814; \ p=0.000 \). Samples with high acceptability scores also received high purchase intent scores, while those samples with lower acceptability scores were less likely to be purchased by the consumer. Similar results have been found by Tepper and Trail (1998) who conducted a study on corn chips. The authors reported that purchase intent of corn chips with varying fat and salt contents was strongly related to degree of liking and that consumers perceived this characteristic as being the most important in their choice of corn chips. Mueller and Szolnoki (2010) also reported comparable results when they found that the purchase intent of a number of white wines was influenced directly only by informed liking. These results highlight the importance of acceptable taste characteristics in the decision to purchase or repurchase a food item. This data suggests that taste remains a highly important factor in the purchase intent process of consumers and is something which they are not willing to compromise on; something that food processors will need to bear in mind when attempting to reduce salt in processed foods like vegetable soup.
Chapter 7  
Salt Threshold Acceptability

7.5 Conclusions
Individual detection and recognition thresholds had no significant effect (p>0.05) on consumer acceptability and purchase intent scores for any of the vegetable soup samples. Salt detection thresholds were found to differ significantly (p<0.05) between male and female consumers, however, this fact had no effect on consumer acceptability and purchase intent scores for any of the vegetable soup samples. The regular salt soup was found to be the most acceptable soup sample. Reduced salt soups which had 0.15% rosemary or 0.1% lactoferrin hydrolysate added were the most liked reduced salt samples. Soups containing a spice blend of rosemary, oregano and sage, were found to be significantly less acceptable (p<0.05) than the above mentioned meals. Significant positive correlations were observed between vegetable soup acceptability scores and purchase intent ratings of the soup samples (r=0.814; p=0.000). These results highlight the importance of acceptable taste characteristics on the decision to purchase or repurchase a food. The inclusion of the consumer in the reformulation process of reduced salt foods was also shown to be a very effective service available to manufacturers in order to retain acceptable sensory scores. The study showed that salt reductions of up to 48% can be achieved in commercial vegetable soup without affecting consumers liking for the meal; however, food manufacturers may need to be willing to accept minor reductions in consumer acceptability as a result (Lucas et al., 2011).
Chapter 8
8. General Discussion and Conclusion

The busy, hectic lifestyles of many of today’s consumers leaves little time to prepare meals from fresh ingredients in the home, which in turn has led to a strong demand from consumers for products that are fresh, safe to eat and most importantly convenient. As a result ready-meals have become a staple in many consumers’ diets and their ever increasing popularity even in these recessionary times bears this out. This diverse product group includes meat, poultry, fish, seafood, pasta, rice and vegetable dishes, which can subsequently be classified as traditional, continental, ethnic, vegetarian or low calorie/healthy option dishes. However, it is currently estimated that approximately 75% of the salt we consume comes from discretionary sources including processed convenience foods such as ready-meals. A substantial body of evidence now exists to suggest that high dietary sodium intake, consumed primarily in the form of sodium chloride, is key factor in the rise in blood pressure with age in industrialised countries such as Ireland. High blood pressure is the main cause of strokes and a major cause of heart attacks - two of the most common causes of death and illness worldwide. Consequently, health agencies are attempting to ensure that this increased demand for convenience based foods will not result in an increased risk to health. Hence, reduction of salt is now one of the major challenges facing food manufacturers especially in the ready-meal sector. An extensive review of the literature indicates that many of these diverse products can often contain very high levels of salt. Therefore, the growing popularity of ready-meals coupled with their reportedly high salt content make them an ideal group of products to reformulate and subsequently study the effects on sensory quality. In Ireland, little data relating to salt content currently exists for commercially available ready-meals. Therefore, a product survey was initially carried out to determine the levels of salt in ready-meals sold commercially in Ireland and is described in Chapter 2. This product survey was then followed in Chapter 3 by a questionnaire to ascertain consumer attitudes towards ready-meals and the current issue of salt content in foods in Ireland. Existing approaches to reducing salt in processed food involve either a gradual salt reduction strategy and/or an immediate removal of high levels of salt with the addition of salt substitutes and flavour enhancers to compensate for loss of flavour. Currently, there is very little published information on the impact of salt reduction on the sensory
acceptability of commercially produced frozen or chilled ready-meals. Therefore, a
study was carried out to determine the effect of a gradual salt reduction program and
the addition of salt substitutes and flavour enhancers on the sensory properties and
acceptability of three commercially produced frozen ready-meals as reported in
Chapter 4. A separate study was then carried out in Chapter 5 to investigate the
usefulness of descriptive sensory analysis in combination with SPME-GCMS
instrumental analysis as a component of a salt reduction strategy. This approach
allowed a more precise impact of salt reductions on the flavour profile and volatile
composition of three chilled ready-meals to be ascertained. Another approach to salt
reduction involves the addition of herbs, spices and whey proteins as natural and more
cost effective alternatives to current salt substitutes and these were examined in
Chapter 6 for their ability to remedy the flavour defects identified in all three reduced
salt chilled ready-meals. The most promising herb, spice and whey protein
combinations were then selected for inclusion into one of the reduced salt chilled
ready-meals i.e. vegetable soup. Thus the final chapter, Chapter 7, focused on
combining all previous work to produce a number of reduced salt ready-meal products
with enhanced sensory properties. Chapter 7 also established the effect of consumer
salt threshold values on the sensory acceptability of several reformulated reduced salt
vegetable soups. The following presents the major outcomes from these research
themes.

In chapter 2 the level of salt in ready-meals available on the Irish market were
surveyed to determine the potential contribution of these products to an Irish adults
RDA of salt. The study found that of 68 ready-meals surveyed, 52 (78%) contained
greater than or equal to 50% of the RDA of salt for Irish adults, currently a maximum
of 4g per day. Eight of the ready-meals contained greater than or equal to the RDA of
salt in a single serving, of which two contained greater than twice the RDA, while one
product contained more than three times the RDA. Only 15 ready-meals contained
less than 50% of the RDA of salt; however, the accuracy of declared salt and sodium
levels was questioned when the products were analysed using an atomic absorption
spectrophotometer. In total, 29% of the surveyed samples (n=20) had declared
sodium levels which significantly differed (p<0.05) from sodium levels determined by
analysis. A follow up survey four years after the original, revealed that of 51 ready-
meals re-examined, 12 had no change in overall declared salt content, 30 declared a
decrease in salt levels on pack with an average reduction of 0.71g of salt, 9 of which were significantly lower (p<0.05). The remaining 9 ready-meals all showed an increase in declared salt content, one of which appeared significantly higher (p<0.05). Overall, this study found that the level of salt in ready-meals in Ireland is very high and despite an overall mean reduction of 0.4g of salt between 2006 and 2010, on average these meals still contained 65% of an Irish adult RDA for salt. The study also highlighted the need for changes to salt labelling legislation to ensure clear declaration of both salt and sodium contents across all food products. The input of the consumer in the development of legislation regarding salt labelling is of vital importance, as any salt labelling system implemented needs to be concise, clear and easily understood in order for it to be effective. Thus, assessing consumer opinion and attitudes towards salt reduction and including them in new salt labelling initiatives will determine the commercial success of reduced salt foods on the commercial market.

In chapter 3 a consumer questionnaire was distributed to 357 consumers in rural and urban areas of Ireland to gain an insight into Irish consumer attitudes towards ready-meals and current sodium issues. The survey revealed that a high proportion of respondents (45%; n=161) were worried about the amount of salt they consumed. Surprisingly, despite this, 58% (n=207) stated they never checked the sodium/salt contents on nutritional labels with 68% (n=244) claiming that sodium/salt contents would never affect their buying choice. The questionnaire also uncovered that 76% (n=270) of Irish consumers consider ready-meals to be high in sodium while 80% (n=285) consider them to be an unhealthy option. However, 50% (n=179) of respondents consumed a ready-meal at least once a week, with a further 17% (n=59) consuming them 2-3 times a week. Of those that did consume ready-meals 78% (n=191) choose them due to their convenience. A total of 75% (n=269) of all respondents said they would choose a chilled ready-meal over its frozen counterpart as they were perceived to be healthier (44%; n=158) and of better quality (54%; n=194). Data from this study again highlighted the need for concerted actions by consumers, manufacturers and retailers to reduce salt levels in Irish ready-meals as despite being reasonably aware of the salt/sodium issue consumers were not making informed choices to reduce sodium/salt consumption.
Chapter 4 investigated the effect of current popular salt reduction strategies on the sensory acceptability of three frozen ready-meals. Initial sensory trials investigated the effect of gradually lowering salt levels in chicken curry, chilli con carne and lasagne ready-meals. Sensory evaluations incorporating paired comparison, triangle and preference tests indicated the extent of potential salt reductions for the various products without a noticeable difference in overall taste and saltiness being detected. Salt levels in chicken curry ready-meals could be reduced by 33%, by 50% in chilli con carne ready-meals and 29% in lasagne ready-meals. Therefore, the maximum amount of salt which could be removed from the ready-meals via a gradual salt reduction strategy equated to a salt reduction of 0.2% in chicken curry ready-meals, a 0.5% salt reduction in chilli con carne ready-meals and a reduction of 0.3% salt in lasagne ready-meals. A range of commercially available salt substitutes and flavour enhancers were subsequently sourced and incorporated into each of the lowest salt ready-meals. Sensory analyses including triangle, paired comparison and preference tests revealed that the incorporation of the amino acid and potassium chloride based salt substitute AlsoSalt® into chicken curry ready-meals allowed salt levels to be reduced to a final concentration of 0.2%, an overall salt reduction of 66%, without panellists detecting a noticeable difference in saltiness. The addition of a number of different commercial salt substitutes in chilli con carne ready-meals, in particular Provesta® 512 a nucleotide yeast extract, compensated for both loss in flavour and in the intensity of flavour due to salt reduction. Finally, the addition of the popular salt substitute potassium chloride (KCl) into lasagne ready-meals resulted in salt levels being reduced to a final concentration of 0.55% salt, an overall salt reduction of 48%, without compromising consumer acceptability, salty taste and sensory preference for the meal. Concerns over the use of KCl based salt substitutes imparting bitter notes at the levels used in this study for all three ready-meals were not justified.

In chapter 5 the impact of salt reductions on the sensory characteristics and volatile composition of chilled ready-meals was investigated as an initial component of a more in-depth salt reduction strategy. Regular and reduced salt versions of vegetable soup, chicken supreme and cottage pie ready-meals were profiled using flavour profile descriptive sensory analysis coupled with solid-phase microextraction (SPME) and gas chromatography mass spectrometry (GC-MS) instrumental analysis.
Reduction of salt in the vegetable soup ready-meal had a significant effect \((p<0.05)\) on the sensory attributes “green colour”, “sweet flavour” and “pepper flavour”. Sensory data for chicken supreme revealed that the attributes “sweet flavour” and “uneven surface colour” were significantly higher \((p<0.05)\) in the reduced salt ready-meal. While salt reduction in the cottage pie had a significant impact on the attributes “uneven surface colour”, “oily flavour”, “oily surface shine” and “translucent appearance”. SPME-GCMS analysis revealed a ‘salting-out’ effect in the regular salt soup with significantly higher concentrations of terpenes and thioethers identified in comparison to its reduced salt counterpart. In comparison, SPME-GCMS analysis revealed a higher proportion of terpenes and aldehydes present in the headspace of both the reduced salt cottage pie and reduced salt chicken supreme ready-meals. Partial least squares regression (PLSR) of ready-meal data identified several significant positive relationships between volatile compounds identified and several sensory attributes associated with the regular salt ready-meals. Information of this nature can potentially be used in a reformulation strategy based on monitoring changes in volatile profiles arising from a reduction in salt which would then allow manufacturers’ to select specific salt substitutes which are compatible with the volatile profile of the original salted product.

In chapter 6 a range of herbs, spices and whey proteins were added into the reduced salt ready-meals studied in chapter 5 to determine if they could act as natural salt substitutes to replace the loss in flavour in each of the meals. Individual addition of garlic, rosemary, oregano and sage at varying concentrations significantly \((p<0.05)\) improved the acceptability of vegetable soup, chicken supreme and cottage pie. The use of acceptability tests as a method to direct the formulation of proprietary spice blends proved successful and their addition into both cottage pie and chicken supreme meals significantly increased acceptability \((p<0.05)\). However, both clove and pimento proved unacceptable additions to all three ready-meals tested. The addition of two hydrolysed whey proteins significantly increased mean acceptability scores \((p<0.05)\) for each meal at all addition concentrations. Thus, the use of herbs, spices and whey proteins show potential as natural salt substitutes.

In chapter 7 the most successful herb, spice and whey protein combinations identified in Chapter 6 were selected for inclusion into the reduced salt vegetable
soup. A consumer acceptability study was conducted firstly to ascertain consumer response to the newly reformulated reduced salt meals, and secondly, to determine whether individual high or low salt taste thresholds affect acceptability and purchase intent scores. Mean detection and recognition thresholds (± SEM) were found to be 10.03 ± 0.78 mM and 22.23 ± 1.27 mM, respectively. No significant difference (p>0.05) in detection and recognition thresholds was observed between male and female consumers. Individual detection and recognition thresholds had no significant effect (p>0.05) on consumer acceptability and purchase intent scores for any of the vegetable soup samples. Therefore, oral sensitivity to salt taste was not a factor in the acceptance of regular or reduced salt vegetable soups. Of the five samples of vegetable soup presented to consumers the regular salt soup was found to be the most acceptable. However, no significant difference (p>0.05) in acceptability and purchase intent scores were found between the regular salt soup and three of the reduced salt samples. Reduced salt soups with the individual addition of either 0.15% rosemary or 0.1% whey protein hydrolysate were the most acceptable reduced salt samples, while soups containing a spice blend were found to significantly less acceptable (p<0.05) than all other meals. Significant correlations were observed between vegetable soup acceptability scores and purchase intent ratings of the same samples (r=0.814; p=0.000). These results once again highlight the importance of both taste improvement with the inclusion of consumer input into the reformulation process of reduced salt foods.

The present study has identified several successful salt reduction strategies that may potentially be effectively applied to reduced salt ready-meals. Future research possibilities that incorporate flavour acceptability along with other sensory and technical properties such as texture and mouth-feel assessments are also of interest for inclusion into salt reduction strategies. These more sophisticated salt reduction strategies should assist food manufacturers in meeting the proposed 2012 salt reduction targets of 0.63g salt (250mg sodium) per 100g in ready-meals and 0.58g salt (230mg sodium) per 100g in soup, as set by organisations such as the Food Standards Agency (FSA) in the UK and the Food Safety Authority of Ireland (FSAI). These more sophisticated salt reduction strategies will minimise manufacturers concerns regarding adverse effects on the sensory properties of their products without loss of consumer loyalty and market share.
Chapter 9
9. Recommendations to Industry

A principal objective of the present work was to develop a range of reduced salt ready-meals with enhanced sensory properties. It is hoped that the following recommendations to the ready-meal industry in Ireland will assist them in developing reduced salt products with enhanced taste properties, which will ultimately help them to achieve the FSAI salt reduction targets of 0.63g salt (250mg sodium) per 100g in ready-meals and 0.58g salt (230mg sodium) per 100g in soup by 2012.

- The branding of ready-meals with reduced salt contents should provide clear and easy to understand information on salt content.

- Irish consumers are not making informed choices with regard to their salt intakes. Therefore, in order for ready-meal manufacturers to achieve FSAI salt reduction targets, reductions in salt should not be made without developing a clear understanding of the sensory implications of the reformulation process.

- Salt reduction strategies must not only take account of their impact on sensory acceptability but also other aspects most notably microbiological safety and processibility.

- A gradual salt reduction strategy can be successfully applied to ready-meal products however, the level of salt reduction attainable will be very much product and process specific.

- By adopting a gradual salt reduction strategy the following salt reductions can be achieved without adversely affecting sensory properties and consumer preference for the meals:
  
  - Salt reduction of up to 33% can be achieved in chicken curry ready-meals.
Salt reductions of up to 40% can be achieved in chilli con carne ready-meals.

Salt reductions of 29% can be achieved in lasagne ready-meals.

- Adoption of a gradual salt reduction strategy made it possible to achieve the FSAI salt reduction targets of 0.63g salt (250mg sodium) per 100g in chicken curry and chilli con carne frozen ready-meals.

- Addition of salt substitutes and flavour enhancers can allow manufacturers to further reduce the level of salt present in these ready-meals; however, sensory analyses will play a key role in selecting a substitute compatible with the product. For example, the following recommendation can be made with regard to the addition of salt substitutes and flavour enhancers to frozen ready-meals.

  - Incorporation of 0.4% AlsoSalt®, a mixture of the amino acid l-lysine and potassium chloride, into chicken curry ready-meals allows salt levels to be reduced to a final concentration of 0.2%, an overall salt reduction of 66%.

  - The use of 0.5% Provesta® 512, a commercial nucleotide yeast extract, in chilli con carne ready-meals allows for the salt content to be reduced to a final concentration of 0.45%, an overall reduction of 60% salt.

  - The addition of 0.5% potassium chloride (KCl) into lasagne ready-meals facilitated a reduction in salt levels being reduced to a final concentration of 0.55% salt, an overall salt reduction of 48%.

- The addition of salt substitutes into all 3 frozen ready-meals made it possible to achieve the FSAI salt reduction targets of 0.63g salt (250mg sodium) per 100g in ready-meals.
• Consumers perceive chilled ready-meals to be healthier and of better quality than their frozen counterparts, therefore, the use of commercial salt substitutes/flavour enhancers may not be desirable as consumers will perceive these ingredients as unhealthy additives. Thus, the addition of herbs, spices and whey proteins into ready-meals have potential as new natural alternatives to current commercial salt substitutes.

• The addition of key herbs and spices individually can help compensate for shortfalls in sensory acceptability for chilled ready-meals. The following product specific recommendations can be made:

  ➢ The individual addition of 0.25% rosemary, oregano and sage and 0.15% garlic into reduced salt cottage pie ready-meals increases acceptability scores up in line with the commercial regular salt cottage pie

  ➢ The individual addition of 0.1% garlic, oregano and sage and 0.15% rosemary into reduced salt chicken supreme ready-meals results in mean acceptability scores which exceed those of the commercial regular salt product.

  ➢ The individual addition of 0.1% garlic, oregano and sage and 0.15% rosemary into reduced salt vegetable soups results in sensory scores which were comparable with the commercial vegetable soup.

  ➢ The use of the whey protein lactoferrin in both its intact and hydrolysed forms increases acceptability of cottage pie, chicken supreme and vegetable soup ready-meals, at all addition concentrations.

  ➢ The use of pimento and clove in reduced salt ready-meals is not recommended due to their adverse effects on the sensory acceptability of cottage pie, chicken supreme and vegetable soup ready-meals.
• Additional reductions in salt content can be achieved by using combinations of herbs and spices without compromising sensory acceptability. The following product specific recommendation can be made for chilled ready-meals:

- Incorporation of 0.25% of a spice blend consisting of 1.5 parts garlic, 2.5 parts rosemary, 2.5 parts oregano, 2.5 parts sage and 1 part pimento into reduced salt cottage pies results in acceptability scores higher than those of the commercial regular salt cottage pie

- A mixture of garlic, rosemary and sage (2.5:1.5:1), added at a concentration of 0.1%, significantly improves the acceptability of reduced salt chicken supreme ready-meals.

- The addition of spice blends in vegetable soup ready-meals is not recommended due to the negative effect on the sensory properties on the meals.

• The addition of the above herbs, spices and whey proteins, either in combination or alone into all 3 chilled ready-meals made it possible to achieve the FSAI salt reduction targets of 0.63g salt (250mg sodium) per 100g in ready-meals and 0.58g salt (230mg sodium) per 100g in soup. By using these ingredients the following reduced salt concentrations are achievable in chilled ready-meals:

- Cottage pie - 0.35g salt per 100g

- Chicken supreme - 0.33g salt per 100g

- Vegetable soup - 0.45g salt per 100g.
Chapter 10
10. Bibliography


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Chapter 11
11. Publications

11.1 List of Peer Reviewed Papers from Thesis


11.2 List of Other Publications from Thesis


