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Ollscoil na hÉireann, Corcaigh

National University of Ireland, Cork

Development, Assessment and Optimisation of Meat Systems for the Aging Consumer through Processing and Packaging Modification

Thesis presented by

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For the degree of

Doctor of Philosophy in Food Science and Technology

University College Cork

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April 2018

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Declaration

This is to certify that the work I am submitting is my own work and has not been submitted for another degree, either at University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork concerning plagiarism.

Certified by:

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Paula Conroy

Acknowledgements

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I would like to dedicate this thesis to my four grandparents Nana, Dan, Nana & Willie.

Abstract

In response to the growing population of those aged over 65, it is essential we prepare for better quality of life not just increased life years. Sensory decline impacts, not just the way we perceive flavours, but the way we see food and the manner in which we handle food. The studies reported in this thesis examined the effects of sensory decline across a wide age cohort using different meat products. The thesis falls under two parts. Part 1 focused on the food aspect of sensory decline which assessed the impacts of texture modification, fat and salt-reduction, salt-substitution and flavour enhancement; all of which resulted in the development of the most enhanced product that incorporated aging consumer needs. Part 2 focussed on the decline in cognitive and physical ability which occurs as a result of the aging process in order to develop a more suitable, convenient and safe food package for the aging consumer. This thesis offers a design for establishing meal solutions for the elderly consumers based around meat products. Of all product attributes, texture was found to be a major determinant in establishing preferences in various age cohorts. It was found that softer foods which were easier to chew and swallow were favoured by older age cohorts. Flavour differences determined among varying age cohorts was also noted. Preferences for fat, fat-replacers, salt and salt-replacers were established. A consistent decreased perception for salt was noted in study participants aged 41-64 in three studies. The use of trained and consumer panels allowed for the development of the 'ideal' processed meat product which was then presented to older consumers in the elderly-friendly packaging formats which were highly accepted. Understanding the needs and requirements of the elderly consumers is paramount in encouraging independent, safe and healthy living of these individuals in our community. It is hoped that this study provides some evidence to educate and assist in this process.

Publications

1. Sensory capability of young, middle-aged and the elderly Irish assessors to identify beef steaks of varying texture. Conroy, P. M., O'Sullivan, M. G., Hamill, R. M., & Kerry, J. P. (2017). *Meat science*, *132*, 125-130.

2. Sensory optimisation of salt-reduced corned beef for different consumer segments. Conroy, P. M., O'Sullivan, M. G., Hamill, R. M., & Kerry, J. P. (2018). Under review *Meat Science.*

3. Impact on the physical and sensory properties of salt-and fat-reduced traditional Irish breakfast sausages on various age cohorts acceptance. Conroy, P. M., O'Sullivan, M. G., Hamill, R. M., & Kerry, J. P. (2018). *Meat Science*, *143*, 190-198.

4. Sensory analysis of MSG flavour-enhanced traditional breakfast sausages: A consumer age profile. Conroy, P. M., O'Sullivan, M. G., Hamill, R. M., & Kerry, J. P. (2018). Under review, *Meat Science.*

5. Quantitative Descriptive Analysis (QDA) of salt-and fat-reduced traditional breakfast sausages containing Monosodium Glutamate (MSG): Development of a flavour wheel. Submitted to *Appetite.*

6. Sensory profiling and external preference mapping of young- to middle-aged and the elderly consumer groups. Conroy, P. M., O'Sullivan, M. G., Hamill, R. M., & Kerry, J. P. (2018). Submitted to *Appetite.*

7. The need for food packaging solutions for the elderly consumers in Ireland. Conroy, P. M., O'Sullivan, M. G., Hamill, R. M., & Kerry, J. P. (2018). *Submitted to Food Packaging and Shelf Life.*

Poster presentations at National and International conferences

1. Sensory differences between young, middle aged and the elderly assessors for beef steak of varying texture. Conroy, P. M., O'Sullivan, M. G., Hamill, R. M., & Kerry, J. P.

ICOMST (International Conference of Meat Science & Technology) (2017) Bangkok, Thailand

2. The reduction of Na and fat levels in traditional breakfast sausages developed for the elderly and the effects on physiochemical and sensory properties. Conroy, P. M., O'Sullivan, M. G., Hamill, R. M., & Kerry, J. P. **ICOMST (2017) Bangkok, Thailand.**

3. Salt reduction and potassium replacement perception of traditional corned beef in different age (18-85) cohorts. Conroy, P. M., O'Sullivan, M. G., Hamill, R. M., & Kerry, J. P. **ICOMST (2017) Cork, Ireland.**

4. Consumer attitudes and expectations of food packaging. Conroy, P. M., O'Sullivan, M. G., Hamill, R. M., & Kerry, J. P. **ICOMST (2017) Cork, Ireland.**

5. Comparing the ability to identify MSG in trained and untrained panels. Conroy, P. M., O'Sullivan, M. G., Hamill, R. M., & Kerry, J. P. **Pangborn Sensory Symposium (2017) Rhode Island, USA.**

6. Consumer attitudes and expectations of meat, meat products. Conroy, P. M., O'Sullivan, M. G., Hamill, R. M., & Kerry, J. P. **Pangborn Sensory Symposium (2017) Rhode Island, USA.**

Oral Presentations at National Conferences

1. Sensory capability of young, middle-aged and the elderly Irish assessors to identify beef steaks of varying texture. **ICOMST (2017) Cork, Ireland.**

2. Preference mapping of flavour optimised traditional low fat and low salt Irish breakfast sausages. **Nursten Symposium (2017), Belfast, Northern Ireland.**

Awards

1. Oral Presentation Award. **Nursten Sympoium (2017), Belfast, Northern Ireland.**

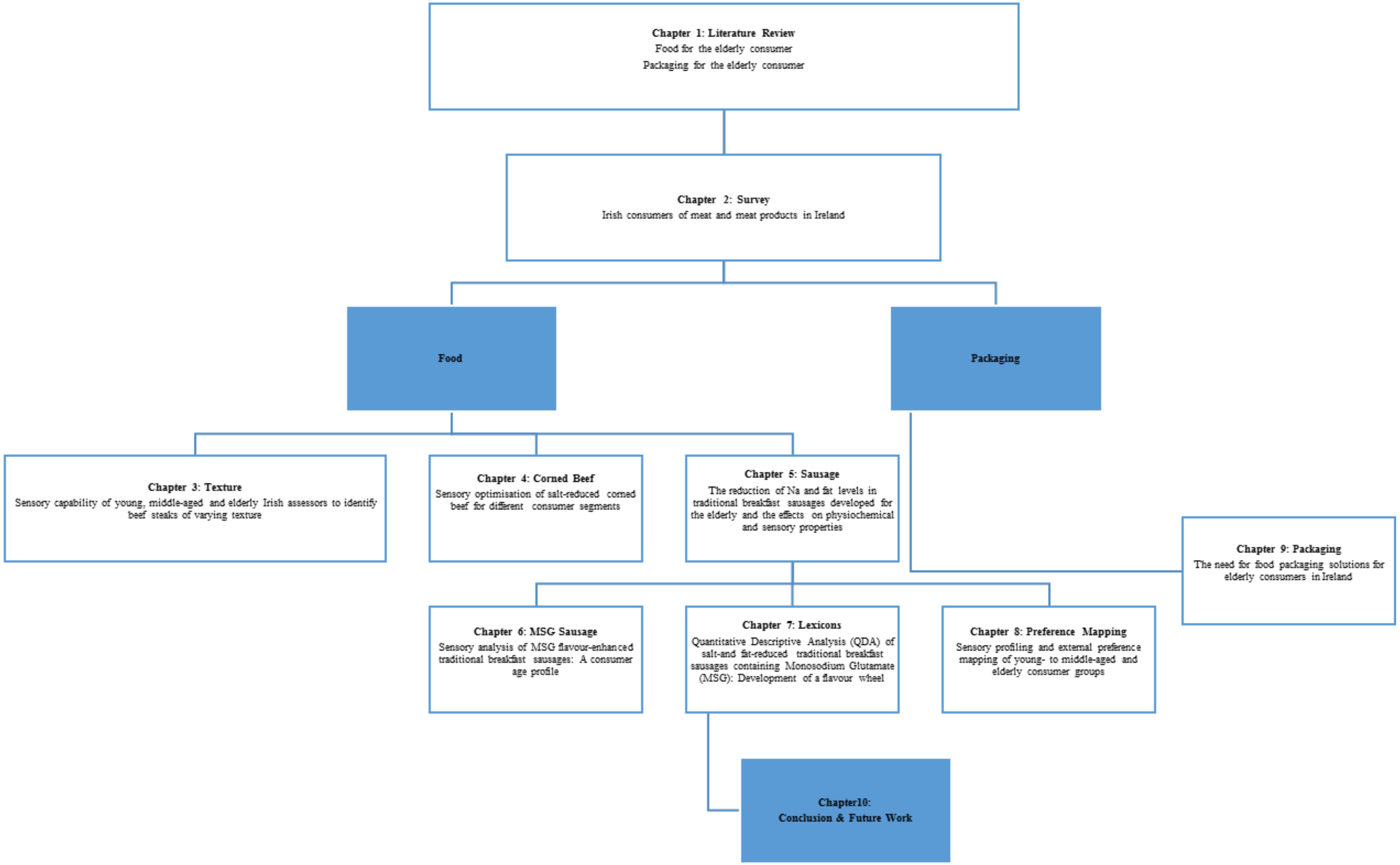
List of abbreviations

Abbreviation	Description
AMD	Age-Related Macular Degeneration
AMSA	Americian Meat Science Association
ANOVA	Analysis of Variance
APLSR	ANOVA – Partial Least Squares Regression
ASHT	American Society of Hand Therapists
BMD	Bone Mineral Density
BP	Blood Pressure
$CaCl_2$	Calcium Chloride
CHD	Coronary Heart Disease
CSI	Consumer Satisfaction Index
CSO	Central Statistics Office
CVD	Cardiovascular Diseases
DTI	Department of Trade and Industry
EHLASS	European Home and Leisure Accident Surveillance System
FDII	Food and Drink Industry Ireland
FIRM	Food Institutional Research Measure
FSA	Food Safety Authority
FSAI	Food Safety Authority of Ireland
GPA	Generalised Procristear Analysis
HHD	Hand Held Dynamometer
HF	Heart Failure

HG	Mercury
HLY	Healthy Life Years
HPLC	High Performance Liquid Chromatography
IHD	Ischemic Heart Disease
ISO	International Standards Organisation
IUNA	Irish Universities Nutrition Alliance
KCL	Potassium Chloride
Kl	Potassium Lactate
LCFA	Long Chain Fatty Acids
LDL	Low-Density Lipoprotein
MFA	Multiple Factor Analysis
Mg	Milligrams
MSG	Monosodium Glutamate
NaCL	Sodium Chloride
NaR/Rna	Reduced Sodium Salt
NFQ	National Framework of Qualifications
OECD	Organisation for Economic Cooperation and Development
PAD	Peripheral Arterial Disease
PC1	First Principal Component
PC2	Second Principal Component
PCA	Principal Component Analysis
PCS	Packaging Standards Council
PLS	Partial Least Squares
PTH	Parathyroid Hormone

QDA	Quantitative Descriptive Analysis
RDA	Recommended Daily Allowance
SBP	Systolic Blood Pressure
SEM	Standard Error of the Mean
SFA	Saturated Fatty Acids
SPSS	Statistical Package for the Social Sciences
TG	Transglutaminase
UCC	Univeristy College Cork
WHO	World Health Organisation
WR	Weber Ratio
Yrs.	Years

Thesis overview



Introduction

Healthy aging is a great challenge of our growing the elderly population. The rationale behind food choices of this population is detrimental for healthy aging. Adequate nutrition is necessary for health, quality of life and vitality. Unfortunately, for a number of reasons, many seniors are not eating as well as they should, which can lead to inadequate nutrition or malnutrition, easily being mistaken as a disease or illness. Therefore, there is a requirement to support the food industry in better understanding the nutritional and food desires of the elderly consumer. Meat4Vitality: Enhancement of texture, flavour and nutritional value of meat products for older adults was launched in 2012. The project followed three themes: food processing technologies, food structures and novel processing technologies with a view to optimise meat processing, formulation and packaging technologies in relation to food structure, flavour, nutritional content and consequently functional performance with a view to providing case studies and tools that would enhance the ability of Irish meat processors to tailor meat products to the requirements of older adults.

The key objectives of this project was to: generate scientific data on the association between sensory physiology and food preferences study degradation of sensory capability during the process of ageing and determine how this affects the elderly's food preferences and general wellbeing and also to understand how older people deal with issues related to food and food packaging.

This project was divided into 9 tasks. This thesis was part of Task 3: Enhancing the flavour profile of traditional meat products to enhance appeal for older adults and Task 5: Development of convenient, safe and easy to open ready-to-heat products for older adults.

The last 7 studies of this thesis are part of the Meat4Vitality project. The first two studies of the thesis describe studies that were conducted to gain a better understanding into the project. This included a comprehensive literature review split into two sections. Section one examined the current research into how the elderly perceive food. The second section examined consumer feedback on meat and meat products in Ireland.

CHAPTER 1

1. Introduction

1.1 Food for the elderly consumer

1.1.2 Definition of Aging

Ageing is a process in which we have little control over. ‘Older people’ are often defined according to many characteristics. They include age, change in social role and functional abilities. In developed countries older age is usually defined in accordance to retirement from paid employment and receipt of a pension, at 60 or 65 years. From a medical point of view, treatment of the elderly, which is referred to as geriatrics, usually starts from the age of 65 years old (Sieber, 2007). There are many definitions of the elderly and old age; however there is no general agreement on the age at which a person becomes old. According to the World Health Organisation (WHO), most globally developed countries have acknowledged 65 years of age as a definition of 'the elderly' or older adult (WHO, 2013). Many people 65 years and over are healthy and independent. However, a large number of the elderly people, especially those 85 years and over, are in need of assistance and health care (Rothenberg, Ekman, Bülow, Möller, Svantesson, & Wendin, 2007). The terms the elderly and old age have subsequently been divided. Chronological age may be subdivided into younger old (65-74), old/mid-old (75-84) and oldest old (85+) (Given & Given, 1989). Similarly, Field & Minkler, (1988) defined the elderly as young old (60-74), old (75-84) and very old (85+).

1.1.3 Aging Demographic

The growing the elderly population in Europe is one of the success stories of our time. Thanks to medical developments, better diet, better living conditions and improved healthcare, the rapid growth of the elderly demographic has occurred. Those aged 65 years or over will account for 29.1% of the EU-28's population by 2080, compared with 19.2% in 2016. The amount of those aged 80 years or over in the EU-28's population is projected to be more than double between 2016 and 2080, from 5.4% to 12.7% (EUROSTAT, 2015). Ireland's population is also ageing. Those in the over 65 age group had the largest increase in population since 2011, rising by 102,174 to 637,567, a rise of 19.1% according to the 2016 census. The census recorded 456 centenarians, an increase of 17.2% on 2011. Over half a million or 577,171 in this older age group lived in private households, an increase of 19.6%, while those in nursing homes increased by 1,960 to 22,762 (CSO, 2016). Today, 11% are aged 65 years or over (468,000). Within the next 25 years, this will increase to 18% (to over one million people). Projections by the Central Statistics Office (CSO) show that by 2021, the number of the elderly people in Ireland will have grown by 200,000. The numbers over 65 will reach 1.4m by 2046; Ireland already has nearly one million people aged 60 years or older. By 2041, the number of people aged 85 years or older will rise almost five-fold, from 74,000 to 356,000 with the number of centenarians predicted to top 8,500 by 2041. The life expectancy is also predicted to increase. Mortality rates are assumed to decrease, which will result in gains in life expectancy at birth from: 77.9 years in 2010 to 85.1 years in 2046 for males 82.7 years in 2010 to 88.5 years in 2046 for females (CSO, 2013).

1.1.4 Quality of Life

With the increased life expectancy comes an increased burden on the economy and medical services if health status among the elderly is poor. Many studies have been carried out examining whether or not extra years lived have been spent in good or poor health (Katz, 1983; Crimmins, 2004). Disability-free life expectancy examines mortality and disability together, positioning fatal and non-fatal outcomes on a common metric. Such population health indicators have been instrumental in exploring whether the extra years lived have been spent in good or poor health (Robine & Michel, 2004).

1.1.1.5 Health Status

As more people live to older age, the number of age-related susceptibility health problems leads to an occurrence of multiple chronic conditions in the same individual. This may cause decline in functional abilities, as well as social and psychological problems, that may have an impact on their wellbeing and quality of life. Healthy Life Years (HLY) indicator is in the core set of the European Structural Indicators. Its importance was recognised in the Lisbon Strategy. HLY is an indicator of the number of years a person of a certain age can expect to live without disability. The rapid increase in the elderly population results in a greater need to understand changes that occur in the later years of life and the outcomes of these changes. As a person's age increases, so too does the likelihood of them suffering from a long standing illness. Occurrences of harmful behaviour, often established early in life, can decrease the quality of life and cause premature death. Poor nutrition, physical inactivity, tobacco use and harmful use of alcohol contribute to the development of chronic conditions: five of these (diabetes, cardiovascular diseases (CVD), cancer, chronic respiratory diseases and mental disorders) account for an estimated 77% of the disease burden and 86% of the deaths in the European Region (WHO, 2010). Diseases linked with ageing will represent a burden to society. Because older adults demand more from the health service, it is important to understand how to maintain health during the ageing process. According to the WHO, the main age related diseases that occur are as follows: rheumatism, arthritis, stroke, cancer, coronary heart disease and dementia. Many of these diseases have either a dietary cause, or can be at least partly alleviated by dietary change.

1.2.1 Nutrition

There is an increasing amount of research specifying that certain dietary constituents influence the development of age-related diseases, including protein for muscle mass maintenance, certain fats (trans fatty acids, saturated, and polyunsaturated fats) and cholesterol for CVD, glycaemic index and fibre for diabetes, fruits and vegetables for CVD, and calcium and vitamin D for osteoporosis and bone fracture.

1.2.1.1 Protein

Aging is often associated with inadequate intake of proteins (Hébel, 2013) and micronutrients **(**De Groot, Van Den Broek; & Van Staveren, 1999), which can lead to sarcopenia (Cruz-Jentoft et al., 2010), frailty and dependency (Wells & Dumbrell, 2006). Sarcopenia is a syndrome which features loss of skeletal muscle mass and function. It is usually a disease of the elderly. Sarcopenia is characterised by progressive and widespread loss of skeletal muscle mass and strength and it is associated with physical disability, poor quality of life and death. Risk factors for sarcopenia, include; age, gender and level of physical activity. In conditions such as malignancy, rheumatoid arthritis and aging, lean body mass is lost, while fat mass may be preserved or even increased.

There is an important correlation between inactivity and loss of muscle mass and strength and this suggests that physical activity should be a protective factor for prevention, but also the management of sarcopenia (Santilli, Bernetti, Mangone, & Paoloni, 2014). A modified food pyramid entitled ‘MyPyramid for Older Adults’ (Fig 1.1) with illustrated examples of healthful foods in each food group was created by Lichtenstein *et al.* (2008). An emphasis on physical activity is featured at the bottom of the pyramid. Greater physical activity allows for intake of larger quantities of food, which in turn, increases the likelihood that all of the necessary nutrients will be consumed. Also, physical activity helps maintain muscle mass with aging. Increasing protein in the diets of older adults is a controversial topic. Some studies do not encourage the intake of high protein diets as it may be harmful due to the risk of toxicity or impaired renal function **(**Lentine & Wrone, 2004)**.** In contrast, other studies suggest that a diet high in protein aids good health, promotes recovery from illness and maintains functionality in older adults; (Gaffney-Stomberg, Insogna, Rodriguez, & Kerstetter, 2009; von Haehling, Morley, & Anker, 2010; Walrand, Guillet, Salles, Cano, & Boirie, 2011). Houston *et al.* (2008) showed that among men and women with sarcopenia and between the ages of 70 and 79, individuals with the highest protein intake lost the least amount of lean muscle mass over a three-year period (Houston et al., 2008). According to the National Health and Nutrition Examination Survey (NHANES), about 6% of men at the age of 71 and over and about 4 to 6% of women over the age of 50 are not meeting the recommended intake levels (Berner, Becker, Wise, & Doi, 2013). At present, the RDA (Recommended daily allowance) for protein (0.8 g protein/kg of body weight/day) is the same for all adults, regardless of age or gender. Recent studies found that adults aged 65 and older require protein intakes greater than the current RDA (Volkert, Saeglitz, Gueldenzoph, Sieber, & Stehle, 2010; Rafii et al., 2014; Tang et al., 2014). Other studies suggest the current protein recommendations for older adults is too low and that older adults should consume 1.0–1.2g/kg BW (body weight)/day (Volpi et al., 2012) for optimal health. High protein intakes have been related to the preservation of skeletal muscle mass and a reduction in sarcopenia (Chernoff, 2004; Millward, Layman, Tomé, & Schaafsma, 2008). Protein is a highly important nutrient in the elderly community diets. A protein energy liquid supplement given to frail undernourished the elderly people positively impacted upon their emotional functioning (Payette, Boutier, Coulombe, & Gray-Donald, 2002). In another study, oral supplementation with a highly nutritious formula improved depressive symptoms in hospitalised the elderly patients during their recovery period (Gariballa & Forster, 2007). Essential amino acids led to an improvement in depressive symptoms, physical performance, muscle strength and nutritional status (Rondanelli et al., 2011a).

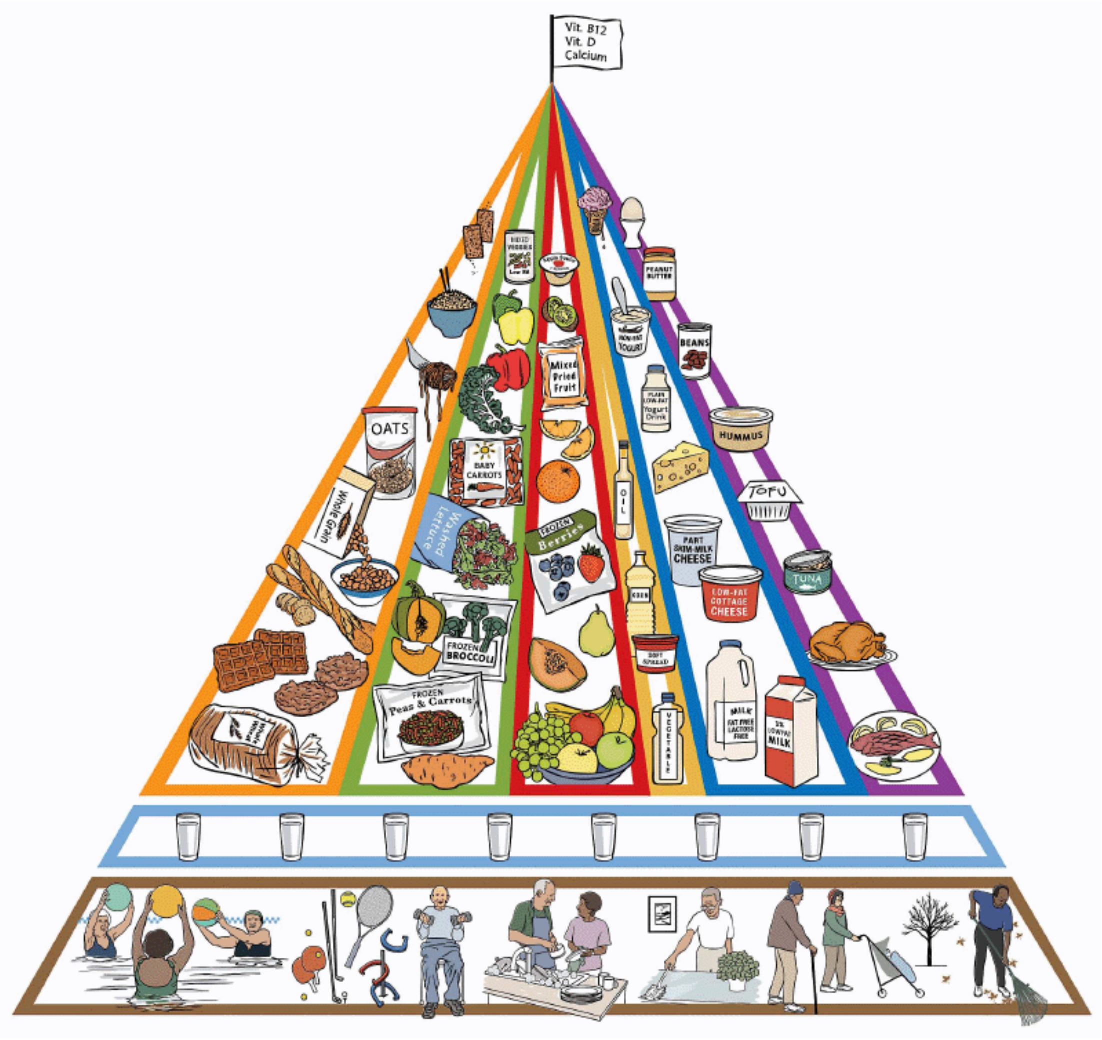


Figure 1.1 MyPyramid for Older Adults (Lichtenstein et al., 2008)

1.1.2.1 Fat, salt and sugar

Diets high in saturated fat, salt and sugar may compensate for a loss of smell due to aging, however the health benefits of these substances may cause detrimental health effects, for example; obesity, diabetes mellitus, hypertension and cardiovascular diseases (Morley, 1990). CVD caused the highest amount of deaths in 2005. It resulted in 5.07 million, or 52% of all, deaths in Europe (Busse, Blümel, Scheller-Kreinsen, & Zentner, 2010). The age-related increase in CVD morbidity and mortality can be appreciated by consideration of the population-based, disease-specific incidence and prevalence rates of CVD, including coronary heart disease (CHD), peripheral arterial disease (PAD), heart failure (HF), vascular heart disease and stroke. The standardised death rate for diseases of the circulatory system among those aged 65 and over in the 28 European countries is 38-times as high as the standardised death rate for persons aged less than 65 (Eurostat - European Commission, 2009). Diets high in sodium have a direct correlation with the incidences of heart disease. In a recent review featuring 23 epidemiological studies (n=274,683), it was determined that the lowest risk of CVD events and deaths occurs at a sodium intake between 2.7 and 5.0g/day (Graudal, Jürgens, Baslund, & Alderman, 2014). Another review study (n=263) agreed with these findings, where it was found that both high (>6 g/day) and low (<3 g/day) sodium excretion was associated with higher mortality and CVD events (O'Donnell et al., 2014). It is well known that dietary fat is also a contributor to CVD. It is well recognised that saturated fatty acids (SFA) increase low-density lipoprotein (LDL) cholesterol, a strong risk factor for CVD (Mensink, 2016). Therefore, dietary improvements have the potential to significantly reduce the prevalence of CVD. Recent studies suggest that insulin resistance is the most important predictor of CVD and type 2 diabetes (Yip, Facchini, & Reaven, 1998; & Demasi, Lustig, & Malhotra, 2017). Epidemiological data has correlated type 2 diabetes with obesity, and a causal relationship between insulin resistance and weight gain has been collected from classical studies in which lean individuals with no previous history of obesity or diabetes developed insulin resistance upon experimental over nutrition (Sims & Danforth, 1987).

1.1.2.1.3 Fibre

The inverse association between dietary fibre (in the form of whole grain foods) and ischaemic heart disease is a long known correlation (Trowell, 1972). Many observational and experimental studies have reported a direct relationship between dietary fibre or fibre-rich foods and total cardiovascular risk or cardiovascular risk factors, such as; hypertension, central obesity, insulin-sensitivity, and elevated plasma cholesterol (Truswell, 2002; Van Horn et al., 2008). Dietary fibre consists of non-digestible polysaccharides, naturally occurring resistant starch and oligosaccharides, and lignin in plants, has been associated with reduced incidence of ischemic heart disease (IHD) and stroke (Khaw & Barrett-Connor, 1987; Wolk et al., 1999). Potential cardiovascular benefits of dietary fibre, include; effects on serum lipid levels, postprandial glucose and triglyceride levels, insulin sensitivity and blood pressure (Wolk et al., 1999). Problems of the bowel have a significant impact on the quality of life for the elderly. Fibre has beneficial effects on gut transit time, crypt formation, intestinal thickness, bioavailability of minerals and vitamins, protein digestion, cholesterol, lipid metabolism, glycaemic and immune function (Donini, Savina, & Cannella, 2009).

1.2.1.4 Calcium & vitamin D

In European countries, the high incidence of osteoporotic fractures leads to considerable mortality, morbidity, reduced mobility and decreased quality of life. In one year the number of hip fractures in 15 countries of the European Community was 382,000 (Gennari, 2001). Genetic factors play a major role in determining bone mass. Controllable lifestyle factors such as diet and physical activity can mean the difference between a frail and strong skeleton. Calcium has been singled out as a key public health concern today. Vitamin D is important for good bone health, however, vitamin D insufficiency is frequent in the elderly populations in Europe (De Groot, Verheijden, De Henauw, Schroll, & Van Staveren, 2004). It aids in the absorption and utilisation of calcium. Supplementation with vitamin D and calcium reduces the risk of hip fractures and other non-vertebral fractures among the elderly people. This effect could be caused by an increase in bone mineral density (BMD) (Chapuy et al., 1992). However, these small changes in BMD suggest that vitamin D and calcium have an additional effect on bone quality, which may explain the reduced fracture frequency. An inadequate intake of calcium and vitamin D leads to poor calcium absorption and increased serum concentrations of parathyroid hormone (PTH). Elevated PTH levels lead to an increased bone turnover and bone loss, particularly in cortical bone (Lips et al., 1982). There is a high prevalence of vitamin D insufficiency in nursing home residents, hospitalized patients, and adults with hip fractures. Throughout life, bone must adapt to the stresses imposed upon it, and its ability to do so depends on both lifestyle and genetic factors (Recker & Deng, 2002). An increase in calcium and vitamin D has proven to exhibit benefits in bone health, particulary in the elderly subjects. Short-term (8 week) supplementation with vitamin D and calcium improved body sway and therefore, may prevent falls and subsequent non-vertebral fractures in the elderly women (n=148) (Pfeifer et al., 2000).

1.1.3 Sensory

During the aging process a decrease in sensory perception, which includes olfaction, gustation, textural and trigeminal senses, audition and vision is often noted. This in turn effects how a person perceives food i.e. texture, taste, smell and appearance. This in turn may result in a reduced desire and intake for foods. Losses in taste perception, as well as distortions of gustatory function, occur with greater frequency in older individuals and these changes are exacerbated by certain medical conditions, pharmacologic interventions, radiation, and exposure to toxic chemicals.

1.1.3.1 Olfaction

1.1.3.1.1 Physiology

The process of olfaction is shown in Fig. 1.2. Odour chemoreceptors are bipolar neurons termed olfactory cells, which are located in the top of the olfactory epithelium at the upper part of the nasal cavity (Schiffman, 1997). The olfactory cell renewal is approximately 30 days (Schiffman & Warwick, 1993). Axons progress through the cribriform plate to the olfactory bulb. The olfactory bulb neurons then project to the limbic system of the brain, which enables the olfactory information to be processed. The olfactory epithelium is covered by numerous hair-like cilia, which are sensitive to odorous molecules and stimulate olfactory sensations (Benignus & Prah, 1982). Odour molecules are perceived in the presence of air due to the volatile property of the molecules. Those two conditions together will enable odorous particles to enter nostrils during sniffing within 1 to 2 seconds (Woods, 1998). The last piece of odour information is relayed to the cortex and the hypothalamus through axons that concentrate in glomeruli (Benignus & Prah, 1982). Aging is associated with a loss of synaptic contacts and a relative decrease in the excitability of intracortical inhibitory circuits (Hortobágyi, del Olmo, & Rothwell, 2006), which in turn causes a decline in sensory processing, motor performance and cognitive function. Additionally, odour identification and categorisation are dependent on olfactory losses, but are also dependent upon age-related cognitive changes. Indeed, with age, active-encoding, active-retrieval and the use of verbal labels can be affected and therefore, will impact upon olfactory capabilities of the elderly along with olfactory physical impairment (Wysocki & Pelchat, 1993).

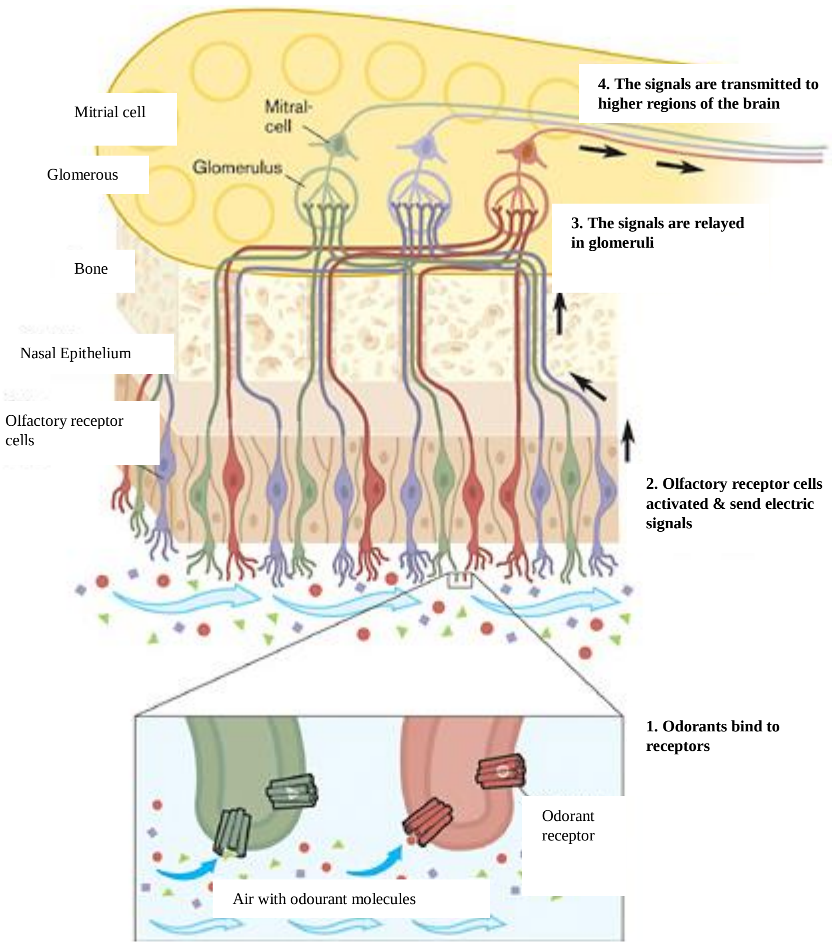


Figure 1.2 Process of olfaction (The Nobel Foundation, 2004)

1.1.3.1.2 Olfaction impairment in the eldelry

There have been numerous studies carried out comparing the sensory differences between younger and the elderly populations (Kremer, Mojet, & Kroeze, 2005). In another study, the elderly subjects who were blindfolded had approximately one half the ability of young subjects to recognize blended foods (Schiffman, 1993). A clear loss in sensory acuity is noted from these studies, however the ability of the younger population to recognise blended foods was shown to disappear when their nose was pinched, thus removing the olfactory contribution in the food perception (Stevens, Bartoshuk, & Cain, 1984). The young lose their advantage in sensory acuity when a nose clip was used in sensory trials (Murphy, 1985; Mojet, Heidema, & Christ-Hazelhof, 2003; Mojet, Christ-Hazelhof, & Heidema, 2005a). The fact that the use of a nose clip impairs the younger subjects taste acuity strongly suggests that young consumers make strong use of their sense of smell in rating taste intensities in difference to the elderly who are less able to do so due to a decrease in olfactory acuity.

1.1.3.1.3 Diseases

The perception of flavour is a result of a combination of volatile compounds and non-volatile compounds. The volatile compounds are the aromas in which we perceive they are detected using the nose. The non-volatile compounds are our sense of taste and they are perceived on the tongue. Odour can be perceived orthonasally via the nasal cavity or retronasally via the nasal and oral cavity. Three intensity levels for olfactory losses are described in the literature (Schiffman, 1997).

They are as follows: Anosmia: absence of smell, hyposmia: reduced sensitivity to smell and diminished ability to perceive suprathreshold stimuli, and dysosmia: distortion of normal smell ability. Hyposmia is the most common olfactory disorder associated with the elderly. The elderly very rarely seek help when they suffer from olfactory losses for numerous reasons. According to Van Toller and Dodd, there is a 20% decrease in olfactory functioning between the ages of 20 and 80 years (Van & Dodd, 1987). As flavour perception is highly dependent on the volatile components of foods, diminishing olfactory function decreases flavour perception in the elderly. Aroma has been stated in the literature to be more important than taste in determining overall flavour (van Stokkom, Blok, van Kooten, de Graaf, & Stieger, 2018).

There has been many studies carried out that demonstrate that old age is associated with a decreased odour perception (Boyce, & Shone, 2006. Baugreet, Hamill, Kerry & McCarthy, 2017; Velayudhan, Morkeh-Wilson, Penny, Gasper, Brugha, Baillon, & Jesu, 2017). There also has been many studies carried out that demonstrate a greater difficulty in the elderly population in odour identification and discrimination (Ormel, De Graaf, Rousseau, & Dumont, 2003; Larsson et al., 2000; & Lehrner, Glück, & Laska, 1999). Schiffman (1992) demonstrated an improvement in quality of life in the elderly due to odour enhancement. The effects include stress and depression reduction, memory retrieval, self-confidence, enhancement of sexuality, better human relations, and modification of sleep (Schiffman, 1992). Adjusting the flavours of food to compensate for diminished odour perception has been proven to increase nutritional status. In a clinical study carried out by Mattes et al. (1990), it was shown that the elderly subjects with taste and smell defects reported frequent taste and food aversions and sometimes lost or gained weight. It has been suggested that the elderly may have a greater tendency towards sweetness to compensate for lower olfactory function (De Jong, De Graaf, & Van Staveren, 1996). According to Philipsten et al. (1995), the elderly subjects recorded a greater flavour intensity with increasing colour intensity. Thus, the elderly may compensate for the losses of olfactory functioning by using their sense of vision (Philipsen, Clydesdale, Griffin, & Stern, 1995). The elderly are usually unaware of a decrease in their olfactory ability. When sensory losses occur over a prolonged period of time, and at a slow rate, the impact of food consumption also gradually declines (Rolls, 1993). This in turn may improve the quality of life in our aging population.

1.1.3.2 Gustation

1.1.3.2.1 Physiology

The gustatory system is responsible for tasting the basic five tastes; sweet, sour, bitter, umami, and salty. It is also responsible for the hedonic and intensity perception of food and drink. The sense of taste is generally associated solely with the activation of taste buds. The act of placing food or drinks in the mouth automatically elicits responses from a different system that monitors the temperature and texture of the food. For this reason, gustation is considered multisensory. In humans, taste sensations are enabled by taste buds situated in various types of papillae situated on the tongue. The taste cells maintain homeostasis and are continuously renewed by the replacement of old cells with new ones. The average turnover rate of taste cells was reported to be about 8–12 days, although some cells in taste buds can survive much longer (Hamamichi, Asano-Miyoshi, & Emori, 2006; Perea-Martinez, Nagai, & Chaudhari, 2013). The larger the number of taste buds, the greater the sensitivity of the person tasting the product (Amerine, Pangborn, & Roessler, 2013). Taste buds have approximately 50 gustatory cells each (Schiffman, 1993). Gustatory cells are stimulated through taste pores. Taste buds are located on the lips, the dorsal surface of the tongue, the tongue check margin, the base of the tongue near ducts of the sublingual glands, the soft palate, the pharynx, epiglottis, uvula and the first third of the oesophagus (Schiffman & Warwick, 1993).

Taste organs on the tongue are complex structures called papillae, which are comprised of an epithelial covering over a broad core of connective tissue, and taste buds and discrete collections of about 40–60 cells within the papilla epithelium. The three gustatory papilla types, fungiform, circumvallate, and foliate, are distributed on the tongue in distinctive spatial patterns. There is also a characteristic number and location of taste buds within the three papilla types. The gustatory papillae and taste buds, therefore, form a patterned organ system that is well suited to detect and localise chemicals on the tongue (Mistretta, Goosens, Farinas, & Reichardt, 1999). The tongue, taste papilla and a taste bud are presented in Fig 1.3. Circumvallate papillae's are the largest papillae and they contain a large amount of taste buds. Those papillae form an inverted "V" shape at the back of the tongue. Most fungiform papillae also comprise of taste buds and have a mushroom shape. They are located on the tip and sides of the tongue. Foliate papillae contain a moderate number of taste buds and are located in the creases along the side of the tongue (Woods, 1998). Food and drink dissolved in saliva acts with taste receptor cells. For this reason, a decrease in the amounts of saliva and speed of chewing might limit the access of taste stimuli to the receptor, thereby reducing the accuracy of taste acuity (Sasano, Satoh-Kuriwada, & Shoji, 2015).

Tongue **Taste Papilla** **Taste Bud**

Figure 1.3: Images of the tongue, taste papilla and taste bud

(Informedhealth, 2018)

1.1.3.2.2 Gustation impairment in the elderly

De Jong et al. (1996) demonstrated that the elderly have a higher liking for the stronger flavour of sucrose and as a result taste stimuli may be concluded to be an age related feature which may be associated with the elderly compensating different tastes. A difference between texture, taste and aroma was perceived differently by young adults compared to the elderly subjects (Kälviäinen, Roininen, & Tuorila, 2003). Schiffman 1993 noted that young subjects need a 6-12 % difference in concentration to perceive a change in NaCL (sodium chloride), KCL (potassium chloride) and $CaCl_2$ (calcium chloride) concentrations compared to the elderly subjects who needed 25% to distinguish a difference in intensity (Schiffman, 1993). There is not yet a clear consensus on the incidence of structural alterations in the gustatory system due to ageing. Some research suggests that ageing may reduce the number of taste buds, papillae or taste-bud density in the epithelium. The effects of aging on taste perception could be more pernounced in older persons than in younger ones (Schiffman, Lindley, Clark, & Makino, 1981; Murphy & Gilmore, 1989; Shimizu, 1997; Fischer et al., 2013), which may imply that taste sensitivity decreases as individuals get older. Whereas there are some studies which suggests that there is no loss in the quantity of taste buds as we age (Bradley, Stedman, & Mistretta, 1985). However there is a mixed consensus on whether or not saliva flow rate is age dependent. Some studies demonstrate that salivary function is relative to age independent, whereby it was noted that healthy older person may have salivary output indistinguishable from that of a younger adult (Ship, Nolan, & Puckett, 1995). In contrast other studies suggest that salivary flow rate is not dependent on age (Fox, 1998).

1.1.2.3 Basic tastes

The chemical stimuli of importance to taste are sugars (sweet), amino acids (umami), sodium chloride and other salts (salty), alkaloids (bitter) and acids (sour). Sugars and amino acids usually are preferred, while alkaloids and acids tend to be avoided. Intake of salts depends on electrolyte balance (Relman & Schwartz, 1952). The gustatory system codes taste qualities and their associated hedonic attributes. The ability to distinguish foods from poisons is so important that it is hard-wired in the receptor cells themselves. It has been long thought that different areas of the tongue perceptives the various basic tastes (Fig 1.4). However recent studies have proven that when taste receptor cells are produced, the cells express dedicated molecular signals that attract the right complement of taste neurons to the brain (Lee, Macpherson, Parada, Zuker, & Ryba, 2017). Another study examining oral taste recognition found that anterior, medium and posterior regions of the tonge had the same taste discriminative capacity (Costa, Santana, & Almeida, 2010).

1.1.3.2.3.1 Sweet

A numer of studies examining age related differences in sweetness perception have been carried out. Jong et al suggested that the elderly may prefer a higher sweetness intensity to compensate for a lower olfactory functioning. They noted that the elderly preferred a higher sucrose concentration in orange lemonade, strawberry jam and strawberry yoghurt, but not in chocolate spread or porridge (De Jong et al., 1996). These results were consistent with those of Enns et al, 1979 who reported a higher preference for aspartame concentration in iced tea in the elderly men (Enns, Van Itallie, & Grinker, 1979). Zandstra & de Graaf found that the elderly preferred higher sucrose concentrations in beverages than younger subjects (Zandstra & de Graaf, 1998). De Graaf et al stated that the elderly have a higher optimal preferred sweetness intensity. They featured a study that proved a sugar concentration five times that in ordinary soft drinks was preferred among the elderly (de Graaf, van Staveren, & Burema, 1996). A similar result was found by de Graaf, Polet, & van Staveren, (1994). Some research suggests that by increasing sweetness intensity other ingredients may be reduced for example Duffy et al 1995 reported that the elderly have a preference for low fat sweet foods (Duffy et al., 1995). Thus by increadsing the sweetness of food for the elderly consumers fat may be reduced. Other studies outline alterior methods for increasing sweetness perception. For example strawberry Schifferstein & Verlegh, (1996) and peach Cliff & Noble, (1990) flavours were found to enhance sweet flavours.

1.1.3.2.3.2 Sour

A number of studies indicate a significant decrease in perception of citric acid, which is associated with the perception of sour, in the elderly subjects (Hyde & Feller, 1981; Cowart, 1989; Murphy & Gilmore, 1989). Chauhan & Hawrysh, (1988) reported that young preferred a lower concentration of citric acid whereas De Graff, (1998) found that they preferred a higher concentration of citric acid (Chauhan & Hawrysh, 1988; Graaf et al., 1994). Changes in bitter taste due to amplification of foods is not the same for different flavours. In a study carried out by de Graff et al 1996 the preference for optimal orange lemonade concentrations were larger than that of boullion and tomato soup flavour (de Graaf et al., 1996). The perception of sour can be manipulated. Sourness is increased by adding menthol and decreased by adding sucrose (Breslin, 1996; Koskinen, Kälviäinen, & Tuorila, 2003). According to Nahon et al 1998 adding orange aroma to a solution of water will increase orange taste intensity, sour taste, fruit taste and a chemical aftertaste. They concluded that it has no effect on sweetness (Nahon, Roozen, & de Graaf, 1998). Various flavour manipulation may be used to enhance or supress other flavours.

1.1.3.2.3.3 Salty

There has been many studies carried out on salt perception in the elderly subjects, however many of these studies are conflicting. Some studies report no change in NaCL perception when the elderly subjects were compared to younger subjects (Hyde & Feller, 1981; Stevens & Lawless, 1981; Weiffenbach, Cowart, & Baum, 1986; Murphy & Gilmore, 1989; Warwick & Schiffman, 1990; Zallen, Hooks, & O'Brien, 1990; & Drewnowski, Henderson, Driscoll, & Rolls, 1996), whereas Cowart (1989) & Murphy & Withee (1986) noted a decrease in the elderly's perception of NaCl (Murphy & Withee, 1986; Cowart, 1989). Little and Brinner (1984) reported a decline in salt perception in tomato juice with age. These results are consistent with that of (Mojet, Christ-Hazelhof, & Heidema, 2001) and (Kremer, Mojet, & Kroeze, 2007a). Whereas Drewnowski et al 1996 found the elderly prefer soups with less salt than young subjects (Drewnowski et al., 1996). Stevens et al (1991) stated that the elderly need twice as much salt as younger subjects do in tomato soup (Stevens, Cain, Demarque, & Ruthruff, 1991). When asked to wear a nose clip the age effects on flavour for saltiness did not change unlike other tastants (Mojet et al., 2003).

1.1.3.2.3.4 Bitter

There have been a number of studies carried out that demonstrate a decrease in the elderly's perception of bitterness (Hyde & Feller, 1981; Stevens & Lawless, 1981; Cowart, 1989; Murphy & Gilmore, 1989; Schiffman et al., 1994). Not detecting the perception of bitterness may be hazardous especially for the elderly consumers, as poisonous or spoiled foods are associated with this basic taste. Others suggest that there is no age related effect with the perception of bitterness (Rolls, 2015). Some substances have been found to hinder the perception of bitterbness. It has been found that sucrose has the ability to supress bitterness (Frank, Van der Klaauw, & Schifferstein, 1993). Sucrose may be able to supress some sensations menthol produces for example bitterness (Kälviäinen et al., 2003). Salt has also been found to supress bitterness perception (Breslin, & Beauchamp, 1995).

1.1.3.2.3.5 Umami

Monosodium glutamate (E621) is a food additive and which functions primarily as a flavour enhancer. It does not enhance the basic tastes (bitter, salty, sweet, sour, and sweet) however, it does enhance the complex flavours of meat, poultry, vegetables and seafood by elevating the taste buds with an umami flavour. It is often described as a meaty - broth like taste. Umami is a savoury taste perception, stimulated by glutamic and aspartic acid and 5' nucleotides (Kurihara, 2009). Schiffman et al 1991 reported a significant decrease in perception among the elderly for umami (Schiffman, Frey, Luboski, Foster, & Erickson, 1991). There have been many studies carried out that demonstrate a preference for meat flavours in the elderly. Schiffman and Warwick 1993 demonstrated that foods enriched with roast beef, ham or bacon flavours was effective in enhancing food intake in the elderly (Schiffman, 1993). Laureati et al 2006 demonstrated that the elderly are willing to eat food that does not feature in their normal diet to include strong flavours such as bacon (Laureati, Pagliarini, Calcinoni, & Bidoglio, 2006a). According to Kremer et al 2005 the elderly perceived chicken flavour as less intense than younger subjects (Kremer et al., 2005). Thus the perception of umami can be considered important in the desire and intake of the elderly for proteinous foods.

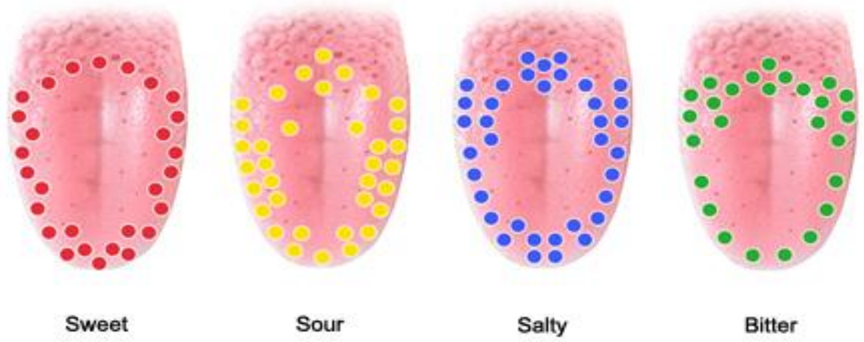


Figure 1.4 : Images of the basic tastes interaction location with the tongue (Informedhealth, 2018)

1.1.3.2.3.6 Fat

Even though fat perception is not listed as one of the five basic tastes. The fact that energy-dense foods are attractive, and thus preferentially consumed, might constitute an advantage inherited from evolution to survive a food scarcity (Drewnowski, 2003). It has been hypothesised that the mechanisms responsible for this specific eating behavior implicates a taste component in the orosensory detection of dietary lipids; long-chain fatty acids (LCFA), in addition to textural, olfactory, and postingestive cues. The interactions between LCFA and specific receptors in taste bud cells elicit physiological changes that affect both food intake and digestive functions. Thus research suggests that fat may be the sixth basic taste (Besnard, Passilly-Degrace, & Khan, 2015). Oils and fats are often related to palatability of food due to their texture and aroma sensory attributes (Pangborn & Dunkley, 1964). Fat influences the temporal profile, the impact of the various flavours, the different flavour notes and when they occur (De Roos, 1997). Perceived fattiness was less pronounced in the elderly subjects compared to younger subjects when analysing waffles (Kremer, Mojet, & Kroeze, 2007b). The elderly have been exposed to high fat levels since childhood. This may be the reason for their preference of high fatty foods compared to younger subjects (Kremer et al., 2005). Fattiness perception includes flavour and mouth feel thus may be the reason for the elderly's preferred perception (Yackinous & Guinard, 2000).

1.1.3.3 Textural

1.1.3.3.1 Physiology

Texture perception is a complex process relating the sensory modalities of vision, hearing, somesthesis and kinesthesis (Christensen, 1984). Texture is perceived in the mouth by the masticatory system, which includes the teeth (functional unit), the jaws (supporting structures), the temporomandibular joints, the muscles involved directly of not in the mastication process, and the vascular and nervous systems supplying these tissues. Any malfunctioning to these units have implications to textural processing (Soboļeva, Lauriņa, & Slaidiņa, 2005).

Auditory texture in some foods is critical for overall acceptability: dried breakfast cereals that do not snap, crackle, and pop, cola that does not fizz, or snacks that do not crunch would lose their identity and acceptability. The sound properties of foods are also reliable indicators of freshness; imagine an apple that did not crunch when first bitten. Visual texture contributes significantly to overall acceptability and suggests the texture to be perceived upon consumption. Visual texture can suggest the freshness of the food; for example, a cut slice of cake may look moist or dry and thus may be perceived as stale or fresh. Tactile texture perceived upon consumption is related to the food matrix and size and shape of the food being consumed (Burgard, 2018).

1.1.3.3.2 Textural impairment in the elderly

Age related differences in texture preferences exist. Texture qualities were proven to be a greater influence on pleasantness for the elderly than the young (Forde & Delahunty, 2002; Kälviäinen et al., 2003; & Kremer, Bult, Mojet, & Kroeze, 2007). Texture is not dependent on one product but it varies from product to product, according to Kalviainen, Salovaara, & Tuorila (2002). Szczesniak 1990 stated that when taste perception is diminished the features associated with texture become more significant in food perception and appreciation (Szczesniak, 1990). Thus age related differences exist in texture perception. It has been demonstrated by many authors that as the viscosity of food is increased the flavour of the food is decreased significantly (Smith & Noble, 1998; Hollowood, Linforth, & Taylor, 2002).

1.1.3.3.3 Dentition

The perception of texture is dependent mainly on the teeth and masticatory musculature. Impaired dental health can change the sensory aspect of eating. Volatile compounds enter the nasal cavity retronasaly when the mastication process occurs. The deterioration in chewing ability in the elderly members of society prevents the detection of flavours from the food (Doty, 1989). According to Papas et al 1989 subjects with one or two sets of dentures have a 20% drop in the quality of their nutritional status compared to those with all of their natural teeth (Papas et al., 1989). Denture wearers usually choose soft food that is easy to form a bolus in the mouth. This food is usually nutritionally compromised (Nagao 1992). The decreased chewing ability associated with dentures may weaken the olfaction and thus may have a direct influence on food preferences (Duffy, Cain, & Ferris, 1999; & Ship, 1999). Dentures that cover the palate may decrease the flow of air between the oral and the nasal cavity and thus weaken retronasal perception (Ship, 1999). An ideal food for those who wear dentures would include a texture that would not adhere to the teeth and would not require extensive mastication (Kalviainen, Salovaara, & Tuorila, 2002). Schiffman 1993 stated that by adding functional fibre to foods may make foods more chewable by softening the foods (Schiffman, 1993). According to Ship, (1999) dentures interfere with chewing and removable dentures reduce masticatory efficiency. This may also add to the decreased perception of foods when compared to younger subjects. Ageing also alters bite force, composition of saliva, muscle fatigue along with dental status (Ship, 1999). Dental status is the main regulator of mastication (Chauncey, Muench, Kapur, & Wayler, 1984). The elderly have shown to compensate for their impaired dental status by adapting coping mechanisms for example increasing the number of chews or increase the time of chewing (Mioche, Bourdiol, Monier, Martin, & Cormier, 2004). Wearing dentures have been proven to lead to many changes in chewing and mouth movements (Wayler, Muench, Kapur, & Chauncey, 1984). Younger subjects have been shown to be more efficient in mastication compared to the elderly subjects (Kalviainen, Salovaara, & Tuorila 2002; Kremer, Bult, et al., 2007). Research suggests that where all teeth are lost, there may be a significant effect on diet, nutrition, general well-being Marcenes, Steele, Sheiham, & Walls, (2003) and quality of life (Locker & Gibson, 2005).

1.1.3.3.4 Chemesthesis

Other textural properties of foods are described as "chemesthesis" and correspond to irritant stimulations of the trigeminal nerves. Chemesthesis is the direct activation of somatosensory nerves by chemical stimuli. Chemesthetic sensations arise when chemicals activate receptors that normally convey other senses such as temperature, pain, touch, or texture. Anatomically, these sensations can occur when somatosensory nerves innervating the skin, mucous membranes, eyes, and oral and nasal cavities have been activated, resulting in cooling, burning, stinging or tingling (Murray & Baxter, 2003).

1.1.3.4 Trigeminal

1.1.3.4.1 Physiology

Chemosensory perception is the result of the interaction between the olfactory and the trigeminal system. The trigeminal nerve is the fifth cranial nerve. Its free trigeminal nerve endings innervate the facial mucosa and the skin and transfer sensory information arising from communication of a physical, thermal, or chemical stimulus with the facial skin or the face's mucosa. The trigeminal nerve's main function is the sensory innervation of the face, such as the perception of touch or pain; it also detects and conveys chemosensory signal generated from ingested or inhaled substances. A very minor portion of the trigeminal nerves' fibers contribute to the motor functioning, such as the control for the muscles responsible for masticating. The trigeminal nerve is therefore identified as a mixed sensory/motor nerve. Different features affect feeling for trigeminal chemosensory perception: aging, sex, olfactory status, or specific diseases are considered determinant factors (Al Aïn & Frasnelli, 2017).

The olfactory system is responsible for the perception of the quality of odours, whereas the trigeminal system conveys sensations such as burning, stinging, pungency, temperature, or pain and thereby serves as an additional guard to protect the airways from harm. Most odorants also stimulate the trigeminal nerve (Wysocki, Cowart, & Radil, 2003). It can be concluded that anosmic subjects may be able to distinguish between odorants based on their trigeminal mediated sensitivity (Laska, Distel, & Hudson, 1997). Nasal trigeminal function is credited as an integral part of human chemosensory perception (Hummel, 2000). Capsaicin from chili peppers, piperine from black pepper, activate temperature and pain receptors in the mouth and menthol also causes chemical irritation (Carstens et al., 2002). These flavours may initiate numbness, heat, cooling, burning and prickling in the mouth. These chemesthetic irritations excite receptors in the trigeminal nervous system. In particular, these sensory responses are a portion of the mandibular branch of the trigeminal nerve, which also serves the teeth, gums, lower lip and lower part of the face. The trigeminal receptors are comprehensive neurotransmitters so their depletion can have a weighty impact the taste of further food (Allison & Work, 2004). Hot spicy foods trigger both pain and temperature receptors. Capsaicin fixes to the same receptors that would respond to heat and physical abrasion. Menthol has an accentuating effect for example if something containing menthol is eaten and followed by a cold food, the cold food will taste even colder. Menthol acts as an appetite suppressant by making food less desirable. Menthol produces a minty taste and aroma and elicits cooling sensations. At low concentrations menthol has a soothing effect, but at high concentrations menthol is irritating.

1.1.3.4.2 Trigeminal impairment in the elderly

Murphy 1983 found that the elderly have a significant higher threshold for detecting menthol than younger subjects (Murphy, 1983). In a study examining the elderly (n=100) and younger subjects (n=100) for their ability to: (i) assign verbal labels from a list of trigeminal type descriptors to six odorants known to have a strong trigeminal component; (ii) discriminate between intensity-matched pairs of these odorants in an odd-ball paradigm. The descriptive profiles given by the elderly subjects correlated significantly with those given by the young controls and thus indicate a high degree of conformity in trigeminal perception of chemosensory qualities between the two age groups. However, the discrimination performance of the elderly subjects was significantly poorer than that of the young. These results suggest that the nasal trigeminal system may experience some degree of age-related impairment but still contributes considerably to the perception and discrimination of chemosensory qualities in the elderly (Laska, 2001).Various flavour compounds can alter the way in which trigeminal sensations are perceived. For example menthol initiates stimuli for trigeminal, gustary and olfaction chemosensory zones Noble, (1996), carbohydrates have the potential to change the volality of flavour compounds

Godshall, (1997) and proteins can change the flavour release through physical or chemical contact with flavour components (Fischer & Widder, 1997).

Cold trigeminal perception can also affect the way in which flavour is perceived. The effect of aroma and colour, and of congruency and exposure on flavour and cooling perception was explored in water. It was shown that olfactory intensity was enhanced by coldness due to perceptual interactions in a congruent mixture (melon odorant, cooling agent, and green colouring) but not in an incongruent mixture (pineapple odorant, cooling agent, and purple colouring). However, when subjects were exposed during 5 weeks to the incongruent mixture, perceptual interactions between olfaction and trigeminal perceptions were promoted. These results are additional evidence of the role of food exposure on perceptual interactions (Petit, Hollowood, Wulfert, & Hort, 2007).

1.1.3.5 Audition

1.1.3.5.1 Physiology

The hearing trail is divided into four sections. Each have a specific function in overall hearing abilities: Outer ear, middle ear, inner ear and the vestibule. The outer ear gains and concentrates the sound and directs it into the middle ear. The outer ear is made up of two parts called the pinna and the ear canal. The pinna is a soft and malleable tissue. It plays an important role in shaping the sound to help the brain work out the direction from which sounds are coming. The ear canal is the physical pathway that directs sound, which has arrived at the outer ear, also known as the pinna into the middle ear. The middle ear starts with the eardrum, which vibrates due to differences in pressure caused by soundwaves. The eardrum is connected to three small interconnected bones called the ossicles that vibrate with the eardrum. The stapes, then passes on these vibrations into the inner ear. The inner ear contains the organs that create our sense of hearing and balance. The cochlea is the organ in that converts mechanical sound vibrations into nerve signals, using hair-like nerve filaments, called hair cells. These hair cells are arranged so that different cells respond to different pitches. The electrical currents produced in the cochlea are then conveyed to the auditory nerve, which passs through several stations in the brainstem before reaching a more complex part of the brain, the auditory cortex, where the information contained sound can interpret and understood. The vestibule, with its semicircular canals, is the organ that provides us with our sense of balance, direction and spatial orientation.

1.1.3.5.2 Audition impairment in the elderly

Hearing sensitivity was found to decrease with increasing age in both genders. A study was conducted examining hearing thresholds among individuals screened for noise exposure, otologic disease, and hereditary hearing loss. It was demonstrated that hearing thresholds declined above the age of twenty years in men, and above the age of fifty years in women. The decline in hearing thresholds of the men was more than twice as fast as that of the women. Women demonstrated the greatest decline in hearing sensitivity in the low frequencies, whereas men showed the greatest decline in the higher frequencies (Pearson et al., 1995).

Functional and cognitive impairments are sources of constant frustration that dampen mood, communicability, general wellness and routine social interactions essential for independent existence (Souter & Keller, 2002). Some studies have found that the untreated the elderly with hearing loss often suffer feelings of sadness, anxiety, depression, insecurity and social isolation, all of which are lessened through cochlear implants or hearing aids

(Abrams, Barnett, Hoth, Schultz, & Kaboli, 2006). Social isolation and feelings of a depressive state have negative impacts on food intake in the elderly subjects. One of the causes of anorexia of aging is the loss of the motivation to eat, which may be due to depression and loss or deterioration of social networks. Social factors, like poverty, inability to shop, inability to feed oneself, and inability to prepare and cook meals, can contribute to decreased food intake in the elderly (Donini, Savina, & Cannella, 2003).

1.1.3.6 Vision

1.1.3.6.1 Physiology

Visual deterioration a well-known factor of aging. The ability to focus, resolve images, distinguish among colours and adapt to different lighting conditions diminish rapidly. Each part of the human eye is an extremely specialised structure. The focus lens gives a small inverted image to an incredibly dense mosaic of light-sensitive receptors, which converts the patterns of light energy into chains of electrical impulses which is relayed to the brian. The retinas are basically outgrowths of the brain, comprising of typical brain cells as well as specialised light-sensitive detectors, the rods and cones. The cones function in daylight conditions and give colour vision. The rods function under low illumination and give vision only of shades of gray. The visual region of the brain is known as the area striata (Moschos, 2014). Vision disorders result from developmental problems, uncoordinated growth of the elements of the eye, disease processes such as inflammation and degeneration, and other changes in the anatomy and physiology of the eye. These disorders affect individuals by reducing their visual acuity, visual fields, colour vision, or stereopsis. Most vision disorders can be treated, though not cured. At least 90% of all problems that people have with their eyes result from refractive errors, strabismus and amblyopia. Less than 10% of vision problems result from diseases, such as senile cataract, senile macular degeneration, diabetic retinopathy or glaucoma.

1.1.3.6.2 Vision impairment in the elderly

In the population over 45 years old, virtually everyone has some vision disorder (Moschos, 2014). Many studies demonstrate clear sensory differences between the young and the elderly populations. According to Beigman & Rosenhall 30% of over those over the age of seventy have deterioration in their vision that cannot be corrected (Bergman & Rosenhall, 2001). Vision was shown to deteriorate during the ageing process when compared to younger adult subjects (Greene & Madden, 1987; Toledo & Barela, 2010). There are four conditions associated with the eyes that cause vision impairment in the elderly. They include: glaucoma, diabetic retinopathy, cataracts, and age-related macular degeneration (Rosenbloom, 1992). Age-related macular degeneration (AMD) is the leading cause of poor vision in the industrialised countries, affecting one in five people between 65 and 74 years of age and one in three people 75 years of age or older (Holz, Pauleikhoff, Spaide, & Bird, 2012). The elderly with AMD must adapt to constant loss of vision. This affects their reading ability and their day to day activities. The majority of older adults who are faced with AMD are psychologically challenged to adapt to on-going and progressive visual loss, which typically occurs as deterioration of the central visual field (i.e. scotoma), affecting reading ability, overall daily functioning, and eating behaviour. In a study comparing the eating behaviour of visually impaired vs healthy subjects eating behaviour of the blind subjects did not differ from that of seeing control subjects. However, the eating behaviour of seeing subjects eating with blindfold demonstrated a clear impact of vision on eating behaviour. When blindfolded, subjects ate 22% less food (P<0.05), had shorter meal durations (P<0.05), and had less decelerated eating curves (P<0.05). Despite a smaller amount of food consumed when blindfolded, the reported feeling of fullness was identical to that reported after the larger meal consumed without blindfold. The importance of vision in regulating our eating behaviour is further stressed in this study. Eating with a blindfold decreased the intake of food, without making subjects feel less full. Eating blindfolded, therefore, may force subjects to rely more on internal signals. These results might be used as an aid in the development of new treatment strategies for obese subjects.

1.1.4.1 Preferences

1.1.4.2 Gender effects on sensory perception

The life expectancy of an Irish man is now 78.7 years, while for women it is 83.2 years Organisation for Economic Cooperation and Development (OECD). During the period 2005-2007, life expectancy was 76.8 yrs. for males and 81.6 yrs. for females in Ireland. In the four years between 2002 and 2006 life expectancy increased by 1.7 yrs. for males and 1.3 yrs. for females. The gender gap now stands at 4.8 yrs., compared with the 5.2 yrs. recorded in 2002. In 1926 male life expectancy was 57.4 yrs. while it was somewhat higher for females at 57.9 yrs. However, while people are living longer and many more are living healthier lives into old age, this is not universal. In the Republic of Ireland, for example, the number of years a man can expect to live in poor health rose from 9.5 in 1999 to 14.7 in 2007. The average woman's likely period in bad health increased from 11.3 years to 16.8 years over the same period (McGill, 2010). There have been many differences in sensory acuity observed between the two genders: Three times more women than men had the combination of low vision and normal hearing aged eighty eight. Normal vision with the combination of moderate to severe hearing loss was more often found in 88-year-old men (Bergman & Rosenhall, 2001). In a healthy Dutch senior population (n=395, age 55–91 yrs.), the prevalence of taste impairment was 1.3% among women and 4.6% among men ($P<0.001$) (Rondanelli et al., 2011b). The total number of years lived in very good or good perceived health was less for men than for women and the proportion of life was similar. Women spent 61% of their remaining life from 65 years without activity limitation compared to men who spent 61% of their remaining life without activity limitation (Robine et al., 2013).

Gender has also been found to influence liking, attitude, affective response, choice, and perception toward food. A study examining differences in hedonic responses of males and females to 4 basic tastes: sweet, salt, bitter and sour was examined. The assessors rated the basic tastes as highly pleasant, neutral and highly unpleasant were measured. Results indicated that the least liked was the bitter taste, followed by the salty, sour and sweet taste which was the most pleasant. The most interesting result was that no difference in pleasantness was observed between genders. The same authors tried to understand emotions that were associated to the perception of those basic tastes. They found that the emotion patterns were similar for genders for the sweet (happiness, surprise and no emotion), bitter (disgust and anger) and mineral water tastes (no emotion, happiness and surprise). On the other hand, emotions reported by males and females differed for the salty (women reported more happiness, less surprise and more disgust) and sour (women reported more happiness) tastes (Robin et al., 2003). Other studies have found gender differences for food preference based on the participants 'health' perception. When evaluating cake products, men gave higher liking scores than women; men have tendencies to rate sweeter foods higher (Michon, O'Sullivan, Sheehan, Delahunty, & Kerry, 2010). This may be due to women favouring more 'healthy' products. Although women have been found to rate healthy meals higher than males regarding pleasure and convenience, (Rappoport, Peters, Downey, McCann, & Huff-Corzine, 1993). However, men were found to prefer more 'comfort meals' such as steak, casserole and soup. while women generally favor snack foods for example chocolate and, ice cream (Wansink, Cheney, & Chan, 2003). One study found that gender differences may be due to women focusing more on their senses and the actual sensation they experience, while men may be focusing more on any cognitive information they receive about the product (Schifferstein, 2006). In a study carried out by Mojet et al. 2001 examining the effects aging had on five different tastes a significant result was obtained for age but not for gender. The older men were still less sensitive than the other age groups and genders (Mojet et al., 2001). There has been some gender effects between tastants reported. Hyde and Feller 1981 reported gender effects for citric acid and caffeine (Hyde & Feller, 1981). Women rated the sourness of citric acid and caffeine higher than that of men. These results are similar to those obtained by Chauhan & Hawrysh 1988 who found that women noted a stronger sour intensity in apple drinks (Chauhan & Hawrysh, 1988). It is evident that food preference is gender specific.

1.1.4.3 Medication effects on sensory perception

Medication use is prevalent in the elderly. Subjects who take daily medication may have an altered sense of smell and taste (Laureati, Pagliarini, Calcinoni, & Bidoglio, 2006b). Approximately 250 drugs have been shown to affect taste (Schiffman 1991). Head and neck irradiation and chemotherapy drugs can disrupt taste bud homeostasis. Irradiation in cancer patients and in animal models induces loss of taste cells and taste buds. Irradiation also diminishes the number of taste progenitors situated at the basal region outside of taste buds. These taste progenitor cells undergo cell cycle arrest or apoptosis within 1–3 days after irradiation but resume proliferation at 5–7 days (Nguyen, Reyland, & Barlow, 2012). Interruption of taste cell renewal may be the main cause of diminishing taste after irradiation. Chemotherapy drugs, such as cyclophosphamide, have also been shown to disrupt the homeostasis of taste buds and papillae (Mukherjee, Carroll, Spees, & Delay, 2013). Thus medication usage is another factor in affecting consumers flavour and food preferences.

1.1.5 Solutions

1.1.5.1 Meat for the elderly consumer

Red meat is an essentiall source of nutrients, which are particularly important for healthy ageing. If meat products can be made more appealing to older adults by modifying their texture, while retaining or enhancing their nutritive value, this could enhance the quality of life of this growing sector of the population. There is a knowledge deficit in the area of understanding the interactive influence of processing, formulation and packaging with meat microstructure and nutritional content to influence nutrient bioaccessability and product acceptability to older adults. Research in this area should prioritise food structure, flavour, nutritional content and consequently functional performance with a view to designing food products that are safe, healthy and have a good sensory acceptance among those aged 65 and over. Various processing methods could include flavour amplification, flavour replacers, modifying crystal size and shape, and using fibre as a fat replacer.

1.1.5.1.1 Methods

1.1.5.1.1.1 Flavour amplification

Stimulus specific losses in chemosensory acuity of the elderly may lead to distorted perception of foods (Koskinen et al., 2003). It has been suggested that enriching foods with stronger flavours may compensate for the sensory decline that is observed in our aging population. In studies carried out by Schiffman 1979, 1983 & Rolls 1992, there was a strong preference among the elderly for the flavour amplified foods that stimulated odour perception (Schiffman & Pasternak, 1979; Schiffman, 1983; Rolls, 1993). In a study carried out on 20 foods including pasta, juices, soups and meats the elderly preferred 19 out of the 20 flavour amplified food products (Schiffman & Warwick, 1989). Flavour enhanced foods were also associated with an improved immune function and an improvement in functional health (Schiffman, 1993). Foods that were flavour amplified with beef, ham or bacon flavours seen an increase in food intake in the elderly subjects. Rolls 1992 suggested that by enhancing flavours a more varied diet may be utilised (Rolls, 1992). According to Griep et al 1997 flavour amplification of food can change food preferences and consumption and may compensate for olfactory losses associated with aging or poor health. For institutionalised the elderly where nutrition and oral problems are a frequent problem flavour amplification is relatively easy to achieve (Griep, Mets, & Massart, 1997). Many odour and taste molecules cause perceptions of heat, cooling and pungency in addition to pure odour and taste (Noble, 1996). Pelchat 2000 carried out a study examining the effects of the elderly people particularly those with poor olfaction, were more willing to accept novel foods than the younger subjects in the study (Pelchat, 2000). Tuorila et al 1994 found that the association subjects had for a novel food compared to a familiar food depended on their own association of a novel food with a well-liked food that they already knew (Tuorila, Meiselman, Bell, Cardello, & Johnson, 1994). According to Furst et al 1996 in their model of the food choice process the most basic factor in food choice is life course which includes the subject's personal, physical social and cultural environments. Past experiences also had a strong influence on how the subjects made their food choices (Furst, Connors, Bisogni, Sobal, & Falk, 1996). Foods that are familiar to the elderly subjects are preferred than new foods (Pelchat, 2000). Traditional dishes also scored highly among the elderly subjects as they reminded them of past experiences (Rappoport, Peters, Huff-Corzine, & Downey, 1992). In a study carried out on traditional Italian foods among the elderly Italian subjects it was found that the elderly confined food preference evolution to childhood. The elderly subjects based their conclusions on simple cooking methods, tradition and sensory aspects when evaluating the traditional food products (Laureati et al., 2006b). According to Mojet et al 2005 the elderly show a remarkable stability in their liking for food (Mojet, Christ-Hazelhof, & Heidema, 2005b). In a study carried out by Mathey et al 2001 repeated consumption of flavour enhanced meals led to an increased food intake, increased body weight, and decreased feelings of satiation (Mathey, Siebelink, de Graaf, & Van Staveren, 2001). Flavour enhancers have been thought to improve food intake in the elderly (Schiffman et al 1988; Schiffman, 1993; Mathey et al., 2001; Mathey et al 2000). MSGs have demonstrated to be effective in increasing food intake among the elderly. In a study investigating the consumption of high protein foods in the elderly it was found that by adding seasonings and sauces containing either monosodium glutamate or glutamaterich ingredients to the meals of older people, a significant increase of energy, protein and fat intake, with no differences between meals with seasoning and meals with sauce. The addition of seasonings and sauces may be beneficial in increasing the food intake of older people as well as promoting overall improvements in nutrition (Best & Appleton, 2013). Schiffman 2000 also showed that the use of the flavour enhancer monosodium glutamate (MSG) in meals for hospital patients resulted in consumption of 10% more calories compared to non-enhanced meals (Schiffman, 2000). Sensory studies have shown that the elderly have a higher detection of MSGs compared to younger subjects. Thus less MSG is needed in the elderly subjects to generate a response (Schiffman, Sattely-Miller, Zimmerman, Graham, & Erickson, 1994; Schiffman et al 1994; Bellisle et al., 1998). Bellisle et al 1991 demonstrated an increased energy intake when MSG's were added to food (Bellisle et al., 1991). Henry et al 2003 demonstrated that natural food flavours in the hospitalised the elderly resulted in an increased food and nutrient intake. Thus there may be a possible role for the use of natural food flavours in the diets of the elderly (Henry et al., 2003).

1.1.5.1.1.2 Flavour replacers

Salt replacemet, partial and full has been successfully carried out using many replacers such potassium chloride (KCl) (Gimeno, Astiasarán, & Bello, 1999; Ruusunen & Puolanne, 2005; Paulsen, Nys, Kvarberg, & Hersleth, 2014; dos Santos Alves et al., 2017). Lithium chloride (LiCl), calcium chloride ($CaCl_2$) (Behrends et al., 2005), magnesium chloride ($MgCl_2$) (Horita, Morgano, Celeghini, & Pollonio, 2011), potassium lactate (Kl) (Gou, Guerrero, Gelabert, & Arnau, 1996; Fulladosa, Serra, Gou, & Arnau, 2009) and magnesium sulfate ($MgSO_4$) (Breslin & Beauchamp, 1995). However, many replacers have undesirable sensory characteristics associated with them. For example KCl is often perceived as bitter (Desmond, 2007), $CaCl_2$ is sometimes associated with bitter tastes and it can cause irritations on the tongue (Kilcast & Den Ridder, (2007). There is limited evidence surrounding the effcet salt replacers have on the elderly consumers. However, implementation of a multi-faceted community-based program was associated with a ~10 % reduction in salt consumption in an Australian regional town in consumers over the age of 56 (n=419). Due to the decline in certain perceptions as mentioned in section 1.1.3, salt replacement may be achievable for the elderly consumers.

Table 1.1: Recent literature suggesting fibre as a viable fat replacer in processed meats

Reference	Fibre type	Addition (%)	Meat Product	Fat reduction (%)
Alakali, Irtwange, & Mzer, 2010	Bambara groundnut seed flour	7.5	Beef burger	N/a
Besbes, Attia, Deroanne, Makni, & Blecker, 2008	Pea and wheat fibre	0.5	Beef burgers	N/a
Cáceres, Garcıa, Toro, & Selgas, 2004	Fructo – oligosaccherides	12	Sausages	35
Campagnol, Dos Santos, Wagner, Terra, & Pollonio, 2013	Soy fibre	1	Fermented sausage	5
Choi *et al*., 2014	Mykgeolli fibre	2	Frankfurters	10
dos Santos Alves *et al*., 2016	Banana flour	N/a	Bologna sausages	60
Huang, Tsai, & Chen, 2011	Oat & wheat fibre	3.5	Sausages	N/a
Kenawi, Abdelsalam, & El-Sherif, 2009	Soy flour & mung bean powder	5	Buffalo meat burger	2
Lin & Huang, 2003	Konjac flour	1	Frankfurters	10
Modi, Yashoda, Bhaskar, & Mahendrakar, 2009	Wheat flour	9	Mutton kofta	8
Modi, Mahendrakar, Rao, & Sachindra, 2004	Legume flour	N/a	Buffalo meat burgers	N/a
Morin, Temelli, & McMullen, 2004	Barley β-glucan	76	Sausages	36.6
Schmiele, Mascarenhas, da Silva Barretto, & Pollonio, 2015	Cellulose fibre	1.3	Pork	50
Zhuang *et al*., 2016	Sugar cane fibre	2	Pork burger	20

1.1.5.1.1.3 Crystal size and shape

The temporal delivery of flavour has been widely studied in recent years and strongly depicts the overall sensory perception of a food (Dötsch et al., 2009). The perception of salt in the solid form is affected by crystal size and shape. In a study examining the effcets of salt crystal sizer on potatoe crisps it was found that salt crystal size impacted upon the delivery rate and perceived saltiness. The smallest crystal size fraction dissolved and diffused throughout the mouth to the tongue saliva faster than the medium and the largest ones; the smallest crystal size fraction also had the highest maximum concentration and greatest total sodium (Rama et al., 2013). The physical form of salt was investigated by changing the physical form of salt so that it becomes more taste bioavailable and therefore less can be added to the products. This involves increasing the efficiency of the salt, changing the structure and modifying the perception of the salt (Angus et al., 2005). Salt flake shape crystals have been shown to have better fat and water binding properties than granular salt when used on red meat batter (Desmond, 2006). Thus by modiying crystal size and shape salt reduction may be achieved without compromising on flavour perception for eldelry consumers.

1.1.5.1.1.4 Fibre as a fat replacer

As fibre consumprion is encouraged in the elderly (section 1.1.2.1.3), it may be a more nutrious fat replacer in processed meat productus. Due to its numerous functional characteristics, dietary fibre is a valuable extender, binder and fat replacement ingredient in manufacturing various meat products. Dietary fibre incorporation in meat products appeals to many health conscious consumers looking for low and reduced fat products.

Recent studies have shown the effects of fibre on processed meat products. Fat was successfully decreased using 1% soy fibre in Fermented sausages. Sugarcane dietary fibre along with pre emulsified sesame oil was demonstrated to improve the texture of meat batter (Zhuang et al., 2016). There are many studies carried out examining the effects of fibre substitution of fat in processed meat products. Examples of recent studies using fibre as a fat replacement can be seen in Table 1.1.

1.1.6 Future

There have been some advances towrads acknowleging the need for specialised food products for the elderly consumer. Some counties are already catering for the elderly consumers food preferences. Japan Care Food Association and Japanese Food Companies have created common standards for food hardness/ smoothness which make it convenient for older people to choose a food with a suitable texture (Furst, Connors, Bisogni, Sobal, & Falk, 1996). The National Nutrition Council has given guidelines of diets for the elderly persons in Finland (Suominen, 2010). The adequate intake of energy, protein and other nutrients (especially vitamin D), fibre and water are highlighted and the OPTIFEL project aims to define and propose vegetable and fruit-based foods that will improve the nutrition and eating pleasure of the elderly populations in Europe. It is essential that projects such as those highlighted above gain recognition from consumers and food industry. (Optifel, 2018)

1.2 Packaging for the elderly

1.2.1 Introduction

Packaging should protect its contents from wastage. It should aid convenient handling from the producer, transport, wholesale, retail and finally to the customer. Packaging is influenced by industry, regulations, and supply chain and customers' demands. According to Brody & Marsh, (1997) packaging of meat is used to avoid contamination, limit spoilage, allow some enzymatic activity to aid tenderness, to reduce weight loss and sometimes to maintain a certain colour characteristic. Most marketers of consumer products still believe that younger audiences are more important targets, that they purchase more products than the elderly consumers and have more years ahead of them to remain loyal customers (Meyers, 2001).

1.2.2 Packaging design

Unfortunately food packaging designed for all consumers is not yet common practice. It requires considerable investments in order to achieve a slight improvement. Packaging should be designed so that those designed to use it should be able to open it. Data on the elderly consumers suggest that convenience, price, user-friendly packaging, single serving packages and health are the most important determinants in food choice (Koehler & Leonhaeuser, 2008). There have been some minor advances in improving packaging open ability for consumers. For example Heinz have changed their trademark glass bottle of tomato ketchup to an easy to open squeeze bottle. They introduced squeezable bottles to target the problem of ketchup not coming out of a glass bottle, then they put the squeezable bottle upside down and standing on the cap. Packaging technologies presents new and different ways of protecting meat products from off flavours, off odours, nutrient loss, texture changes, and discolouration. Such as antimicrobial films, gas flushing, vacuum packing and modified atmospehere packaging. KP salted peanuts have seen a dramatic change since their first product to hit the shelves in the 1940's where the packaging consisted of a tin can which needed a leaver to lift off the lid. Now the KP salted peanuts have a foil bag for freshness that can be easily opened without the need for instruments. The iconic 'Heinz Beanz' tin has undergone some consumer friendly packaging adaptions since its first tin in 1958 such as ring pulls on the cans for convenience. Although the product is synonymous with cans, 2007 saw the introduction of personalised microwaveable snap pots, and in 2010 the fridge pack was launched. These products are illustrated in Figure 1.5. These products have made it easier to open for the general public, however the elderly members may still experience difficulties. Packaging technologies presents new and different ways of protecting meat products from off flavours, off odours, nutrient loss, texture changes, and discolouration.

Figure 1.5: Evolution of well-known food packaging over time, to cater for consumer needs and demands

1.2.2.1 Injury

According to the Department of Trade and Industry (DTI), approximately 67,000 people in the UK attend hospital each year due to accidents involving food or drink packaging (DTI, 1997). The estimated cost of treating the hospital accidents alone is in excess of £12 million each year (Winder, Ridgway, Nelson, & Baldwin, 2002). According to the National Council on Ageing and Older People Report, of those aged 55 years or over who had accidents, 49% occurred in the home or garden. A total of 9% of injuries in the elderly population happened in the kitchen of these 10% were cuts (Garavan, Winder, & McGee, 2001). The cost of injuries includes the cost of medical care, the cost of rehabilitation, disability, loss of earnings, loss of productivity, legal proceedings, loss of quality of life, pain and suffering (Scallan, Staines, & Fitzpatrick, 2001). Of those over the age of 65, 1.2% admitted to hospital in Ireland from the time of 1993-1997 was due to a cut or a pierce to the skin (Scallan et al., 2001). The more elder members of the elderly population tend to stay significantly longer in hospital according to the European Home and Leisure Accident Surveillance System (EHLASS) (EHLASS, 1998), thus increasing demands on medical care and staff resources.

1.2.2.1.2 Sharp Objects

The elderly who do not ask for assistance in opening difficult packages are more likely to suffer the most severe accidents. This may be due to the fact that these people are less likely to give up on difficult packaging, using more extreme attempts to open the packaging for example using sharp instruments. As people age they adapt to more complicated packaging by using tools. They also adapt different approaches to open the packaging (Butters &

Dixon, 1998). Packaging accidents often happen due to the use of a tool for example a scissors or a knife. Injuries may happen due to a breakage of glass when opening jars. The force used by the elderly to open food packages by cutting or piercing may injure them also. The likelihood of packaging accidents is likely to increase due to our growing the elderly population. Injuries caused by knives used in the process of opening packages whereby the respondents noted that the most frequently injured part of the body was the hands (DTI, 1997; & Risch, 2000). People exhibit more caution when opening packaging in their middle age and the elderly age (Winder et al., 2002). Data obtained from the DTI report entitled 'Consumer Safety Research. Domestic Accidents Related to Packaging' gives an insight into packaging related accidents. In 1997 accidents involving knives account for 6% of all the reported packaging associated accidents. The consumers analysed reported that if they are unable to open packs such as those containing cooked meat, cheese, packs of frozen foods, and tamper evident closure bottles easily and quickly, they would resort to using a tool such as pliers, screwdrivers and doorjambs. Consumers tended to used knives rather than scissors, despite packs recommended using scissors, because knives were more readily available and speed was a major requirement. Of the consumers assessed 63% of them use knifes to open food packaging (DTI, 1997). The main features customers seek in food products is safety, quality and convenience, along with production-related attributes (Winger & Wall, 2006).

1.2.2.2 Hand Functioning and Packaging

Hand function often declines as ageing progresses. A decline in hand function is often noted in the elderly. This maybe be due to diseases such as osteoarthritis and rheumatoid arthritis. Both diseases effect certain joints and may cause swelling, pain, stiffness and deformation of the joints (Symmons et al., 2002). This may also lead to difficulty trying to move hands and wrists and trying to squeeze (Carmeli, 2003). A decrease in hand grip limits the elderly’s ability to open packaging (Carse, Thomson, & Stansfield, 2007). The shape of packaging affects the elderly’s ability to open packaging (Berns, 1981). The size, shape and texture of the package determines the grip to be adopted – lateral pinch grip for small lids such as water bottles, tip or chuck pinch for thin film and flexible packaging such as individual serves of yoghurt, cheese and biscuits (Rowson & Yoxall, 2011). According to a survey carried out by Duizer et al 2009 participants (n=99) over the age of sixty indicated that glass containers with corners were preferred over round glass containers, as the edges were thought to make the container easier to open. They also noted that the elderly preferred smaller sized food products due to the small size of their families. They stated a 1L milk container is ideal for storage and usage (Duizer, Robertson, & Han, 2009a).

1.2.2.2.1 Hand Dominance

Left handed people often experience more trouble with opening packaging than right handed people (Winder et al., 2002). Left handed people are also more prone to accidents (Larson, Alderton, Neideffer, & Underhill, 1997). Research by Smithers PIRA has produced some suggestions for improving packaging design. They suggest incorporating the needs of minority groups such as left-handers to develop safe packaging. They suggest that market research be used more exhaustively as a development tool, and that awareness of consumer needs is very important (Page, 2000). It has been found that with adequate design left handed people should not be at a disadvantage over right handed people (Berns, 1981).

1.2.2.2.2 Grip Strength

There are many publications reporting on the ability of the elderly populations to open certain types of packages (Robertson, 2009; Blakey, Rowson, Tomlinson, Sandham, & Yoxall, 2009; Yoxall, Kamat, Langley, & Rowson, 2010; Rowson & Yoxall, 2011). Complaints about the structure of packaging are numerous among the elderly. Child-resistant caps, ‘push here’ lids that refuse to yield and bottle seals that require knives or other tools to remove them are not user friendly for older consumers. Equally disliked are jar lids that are difficult to grasp and turn, anti-tampering devices with obscure or unclear opening instructions and blister packages for tablets that resist efforts to remove the product (Meyers, 2001). Grip strength has been demonstrated to decrease with age, even in the healthy population (Werle et al., 2009). Having a good grip strength is essential for opening packaging. Difficulties in opening packages have been observed due to a decline in hand functioning in the elderly people (Lewis, Menardi, Yoxall, & Langley, 2007). It has been reported that a 70-year-old individual has only 65% the strength of a 20-year-old individual and that arthritic subjects have only 30–40% of the opening strength of a physically able person (Carus, Grant, Wattie, & Pridham, 2006).

1.2.2.2.3 Torque

In a study examining the torque on capped devices on various individuals (n=235) it was concluded that a 70 year old had the strength of a 10-year old child (Alaster Yoxall et al., 2010). Carse et al 2011 compared young adults (n=8) and older adults (n=13) with an instrument devised to mimic the opening of a jar. It featured a split lid, motion tracking markers, force transducers and an inverted lid assembly to monitor the squeeze force and the compression force of the jar. They found that there was a trend for the older adults to use lower squeeze forces in comparison to compressive forces. They also found that older adults built up the torque and opened the jar lid at torque release at a slower rate than the younger adults. Thus, there is need to further examine the different attributes involved in opening packaging. There are more attributes related to packaging opening than the torque test (Carse, Thomson, & Stansfield, 2011). Hand positions, hand actions, hand directions and confirmation of how to open the package should be provided by the products label to ensure that the opening methods are explained fully to trigger the elderly persons memory (Chavalkul,. 2009). Many studies have been designed to define the opening torques of a jar (Peebles & Norris., 2003; Carus et al., 2006). There are some studies which highlight the torques needed by different age groups to remove lids (Carus et al., 2006).

1.2.2.2.4 Dexterity & strength

There are many studies carried out examining the open-ability of packaging. Opening food packaging is a routine activity carried out daily worldwide. The process is often linked with challenges. Opening mechanisms are often the root packaging opening difficulties. The main reasons for the associated problems are the forces required to open packaging, tear tabs that are too small, and the limited ability to see the opening mechanisms (Dittrich & Spanner-Ulmer, 2010). Opening peel-able packaging, such as is used for cheese or meat, causes many problems for older consumers (Heiniö, Åström, Antvorskov, Mattsson, & Østergaard, 2008; & Rowson & Yoxall, 2011). It has been estimated that nearly 20 per cent of older people stop buying certain products because of difficulties opening them (Galley, Elton, & Haines, 2005). Various recommendations have been made to help. For example, the PSC found that tear tapes were appreciated by the elderly consumers. The recommendations are that the length of the tab be identified on the pack in a contrasting colour and the start tab be clearly marked in a primary contrasting colour. Previous studies have demonstrated that 40% of people aged between 62 and 82 years, and up to 78% of patients with hand disorders, have difficulties opening peel-able packaging or are simply unable to do so (Hensler, Herren, & Marks, 2015). A 2007 New South Wales Health Service malnutrition prevalence audit identified that a number of patients in a hospital setting did not eat their food because they could not open the packaging (Matthews, Bartlett, & Hall, 2007).

Dexterity and strength decrease as people age (Shiffman, 1992; Lewis et al., 2007). According to Rowson & Yoxall (2011) age, gender, grip strength, the friction coefficient between the hand and the jar, the wrist strength and the diameter of the container are the factors that effect a consumer's ability to open a cylindrical jar. There are also some nonphysical factors such as cognitive ability, other environmental factors and time pressures. There is a large amount of research conducted into ergonomics (Kong & Lowe, 2005; Zunjic, 2011; Morello, Rossini, Pia, & Tonoli, 2011). Research has also been conducted examining the relationship between grip and comfort (Lewis et al., 2007). Packaging which requires fine manipulation and high levels of grip force cause the most difficulty to disabled consumers. The bulk of these problems appear to be centred on hand strength, dexterity, and the understanding of how packaging should be opened. It can therefore be concluded that packaging openability is a common consumer concern in the grocery industry and those who carry out research in the area.

1.2.2.2.5 Muscle Strength

Sarcopenia is generally defined as an absolute muscle mass below the fifth percentile for healthy adults (Prado et al., 2008). Sarcopenia is a syndrome characterised by progressive and generalised loss of skeletal muscle mass and strength with a risk of adverse outcomes such as physical disability, poor quality of life and death Delmonico et al., (2007) as mentioned. The decreased muscle strength in the elderly subjects hand have been linked with decreasing muscle mass (Metter, Conwit, Metter, Pacheco, & Tobin, 1998). According to the DTI Report 70 yr. olds have 65% of the strength that 20 yr. olds have. It equates to the strength of a 10 yr. old (DTI, 1997). An experiment was designed comparing the elderly (n=6) and young group's (n=2) ability to open a child resistant closure on a screw cap. A multi component load transducer was constructed to measure and calculate the forces required by the different subjects to open the lid. It was noted that the elderly subjects had less control over where they applied the force and torque to bottle closures, thus they use different posture to the younger subjects. There were noted differences between the two groups. The two groups demonstrated different torques and force profiles while opening the bottles (Carus et al., 2006).

1.2.2.2.6 Gender

Inclusive design encompasses design for all consumers. Packaging is an important area of research for inclusive design. All members of society, such as the elderly women, often exhibit extremes of physical dimensions (Alaster Yoxall, Luxmoore, Rowson, Langley, & Janson, 2008) that may limit or inhibit their use of food packaging. Gender also plays a part in packaging preferences. Future senior men frequently using ready-made meals were identified as a promising target segment for the development and marketing of novel ready-made meals (Heiniö et al., 2017). A study was carried out examining the hand strength of the elderly subjects. As expected, the men were consistently stronger than the women ($P<0.0001$). Grip strength decreased with increasing age, depending on the hand and the instrument ($P<0.0001$) (Desrosiers, Bravo, Hebert, & Dutil, 1995). It has been found that the elderly men prefer a higher concentration than all the other age groups (Mojet et al., 2005b; & De Jong et al., 1996).

1.2.2.3 Labelling

Not only can the packaging itself be difficult to open, labels may be difficult to read and comprehend. There are still substantial advances needed in terms of the ease of opening products and the clarity of the Instructions. There are two types of labels; 2D labelling which refers to surface, embossed or imprinted indications which users can see and read to interpret meanings for example: written instructions or a diagram and 3D labelling which includes shapes or embossed markings which the consumer can use to feel to understand its meaning. For example the ridges around a lid of a bottle and the shape of a trigger

(Chavalkul, Saxon, & Jerrard, 2011). A decline in functioning also leads to a decreased ability for the elderly to understand labelling. According to Keates & Clarkson 2003 it may be difficult for some people to see precisely where to tear a transparent film on a jar lid (Keates & Clarkson, 2003b). A decline in seeing, hearing and touching is likely to contribute to the deterioration of perception. According to Stokes 1992 stronger stimuli should be incorporated when designing products for the elderly. These may include a larger text size, and higher colour contrasts between the writing and the background (Stokes, 1992).

1.2.2.3.1 Visual Limitations

Motor deterioration is often focused on when assessing packaging solutions for the elderly. However, less acknowledgment is assigned to visual limitations. Subtle physiological changes often yield loss of visual clarity and sensitivity which will impair the elderly consumer's aptitude to observe the graphic fundamentals of a package visibly (Meyers, 2001). Visual factors may impair the elderly from reading the labelling correctly and thus causing damage to the food or themselves. Some may employ a coping mechanism. In a study carried out by Huang & Dong 2014 interviews were conducted on the elderly subjects who lived independently (n=51). They found that some subjects used a magnifying glass to read labels as reading glasses worn for a long time caused the bridge of her nose to be uncomfortable. They also found that the elderly found following instructions difficult and they needed larger texts, higher contrasts and longer pauses between setting bump steps when digital devices were used (Huang & Dong, 2014).

The use of nutritional labelling is a valuable tool in ensuring the essential nutrients are obtained, however nutrition information on food labels is complex and does not always live up to its potential to communicate effectively (Drichoutis, Lazaridis, & Nayga, 2005; & Hieke & Taylor, 2012). This poses a threat to the nutritional status of the elderly consumers and it may put them at a greater risk of malnutrition. Food label use may have even greater importance for older adults because of their higher risk of diet-related chronic diseases (Post, Mainous, Diaz, Matheson, & Everett, 2010). Instructions on packaging regarding opening the package, cooking methods and reheating methods is extremely important. They provide essential information that insures product quality and safety from a microbiological point of view. Expiry dates are often noted as being too small (Meyers, 2001), this may induce food poisoning if the elderly consumers are not clear on the date of expiration. Three groups of instructions should be used in packaging: full explanation, memory trigger and partial explanation when giving instructions on how to open packaging. They should include information on hand positions, hand actions and hand directions that are required for opening packaging. Clear language should also be used. For the elderly full or partial explanations should be used to indicate how to open the packaging and how to confirm it is opened. Packages with two or more opening steps or unfamiliar opening methods were found to demand more cognitive processing (Chavalkul et al., 2011).

1.2.2.3.2 Colour

Label colours take on special importance for the elderly consumers. Colour coding of packages, or on portions of packages, is frequently utilised by manufacturers to differentiate between similar product varieties (Meyers, 2001). However this may impair viability even further for the elderly consumers. The senses used when opening a package are vision, hearing and touch. Due to a decline in these senses in the elderly they may find it more difficult to open a package due to a decline in visual acuity i.e. colour perception, hearing difficulties, and tactile and pressure sensitivity. Visual acuity and brightness and darkness adaption negatively affects participant's ability to notice, identify and read indications for opening. They found that brightness and darkness adaption negatively affected the elderly's ability to identify indications than colour perception alone. Indication visibility is very important for older people when packaging appearance is unfamiliar (Chavalkul et al., 2011).

1.2.3 Solutions

1.2.3.1 Packaging Designs

A Japanese consumer survey found that consumers preferred packaging that requires low levels of strength to open, can be opened without a tool and the method needed to open the pack would be easily understood (Kozak, Terauchi, Kubo, & Aoki, 2003). The possibility of producing meat packaging that is easier for patients with hand disorders to open was investigated. Patients with osteoarthritis (n=100) were asked to open a meat package with a modified and commercial meat package. The mean consumer satisfaction score indicated that the novel meat packaging was preferred. These results indicate that manufacturers today can produce easy-to-open food packages that afford greater consumer satisfaction. The authors concluded that future packaging would benefit not only people with hand disorders but also the population as a whole (Hensler et al., 2015). A loss of dexterity and strength is often noted as ageing progresses. This can cause problems in opening and managing food. There has been very little research conducted into packaging designs targeted at the more the elderly members of our community. Older people may find it difficult to open and understand packaging for many reasons. This could be due to visual impairments and various physical diseases such as Parkinson's disease, arthritis, rheumatism, or reduced mobility. There has been many recommendations that the consumer's life cycle should be considered while designing packaging (Wikström, Williams, Verghese, & Clune, 2014). Data on the capabilities of the elderly who live alone is scarce. Not only are the numbers of senior citizens increasing the number of this cohort living independently is also increasing. Over half a million or 577,171 in this older age group lived in private households, an increase of 19.6% from the previous census (CSO, 2016). The capabilities of these consumers are very relevant for package design and must be considered in future designs. Consumer perception of packaging is thought to be one of the most important factors influencing new packaging technologies (Coma, 2008). Packaging design can lead to difficulties in opening containers and this in turn lead to the use of inappropriate tools and resultant injuries as discussed previously (Galley et al., 2005).

1.2.3.2 Novel Packaging for the elderly

Novel packaging may be defined as a package whose appearance is unfamiliar to consumers. A common stereotype associated with older people is that they are not willing to change and are not likely to try new experiences (Stroud, Erkel, & Smith, 2005). Such opinions may insinuate older peoples' resistance to change may form a barrier, preventing them from trying new products in novel packages. It has been noted that older people have higher brand loyalty than their younger counterparts (Coles, McDowell, & Kirwan, 2003). The elderly consumer usually buy products with a brand that they know and a package that they are familiar with. Others hypothesise that older people try new products just as younger people do, but their motives are driven differently. Younger people may look for new products that are trendy, whereas older people tend to look for new products that meet their personal, specific needs (Leventhal & Patrick-Miller, 1997). The elderly consumers have shown to try new brands that meet their needs (Ambrosius, 2010). Furthermore, self-perceived age tends to be more useful than physiological age in understanding older people's product and brand consumption (Wilkes, 1992). Despite older peoples' preferences for products with tried and tested branding, it is unlikely that they can completely avoid experiencing new products. Packaging design practice for older people within the terms of this study appears to subscribe to the principle of inclusive design (Keates & Clarkson, 2003a). It has been suggested that "Inclusive design is about maximising the market potential of your products by making sure that the maximum number of people can use them" (Keates & Clarkson, 2003b). Convenience features such as portion-packs are often valued by older people. They value these packages, even if they are more expensive, because they conveniently provide just the right amount of product and preserve the freshness of the products. There is limited research conducted into the requirements and suggestions for food packaging from an the elderly consumer point of view. A list of some of the most recent studies examining the literature on the elderly consumers' needs in food packaging can be viewed in Table 1.2.

Table 1.2: Examples of various studies examining food packaging requirements for the elderly consumers

Reference	Method	Requirements	Sample size	Age (yrs. old)
Duizer, Robertson, & Han, 2009b	Focus Group	Price	13	>60
		Safety		
		Apportionment		
		Recycle		
Ford, Trott, & Simms, 2016	Interviews	Legibility of labels	11	59-85
		Visibility of contents		
		Recycle		
		Open ability		
		Storage		
		Apportionment		
		Legibility of labels		
Heiniö et al., 2017	Survey	Legibility of labels	1239	55-65+
		Recycle		
		Visibility of contents		
		Open ability		
Sudbury-Riley, 2014	Qualitative diary research	Open ability	10	50+

The main factors concerning the elderly consumers from the trials included legibility of labels, ability to recycle, visibility of contents, open ability, price, safety, apportionment and storage. However, older consumers are not likely to switch brands as a result of package preference alone. Packaging must offer significant improvement over current alternatives for the elderly to appreciate its value and influence their Flip-top caps. Older people differentiate between packages that solve real problems and those that are just promotional novelties, whereby the novelties are not worth the extra cost (Meyers, 2001). Branding packaging for the elderly requires consideration. By referring to their age demographic a bias may be placed on the product as they may feel ashamed or old (Costa & Jongen, 2010). The most recent study examining ready-made meal packaging was carried out on Finnish and Dutch 'current' and 'future' seniors. It was found that the ability of easy to prepare readymade meals may allow frail and older consumers to consume a hot meal in situations where they may skip meals (Ziylan, Haveman-Nies, van Dongen, Kremer, & de Groot, 2015). Despite most packaging designers knowing about inclusive design, they had little or no knowledge of how to put it into practice, admitting that older adults were not routinely considered in design processes. The ergonomics research still classifies older adults as "extraordinary" (Carse, Thomson, & Stansfield, 2010).

There a wide range of research to support the concept that the elderly people want to be independent for as long as possible (Duner & Nordström, 2005; & McGarry & Schoeni, 2000). The ability to eat and cook independently, are strongly associated with well-being and increased self-esteem (Gustafsson, Andersson, Andersson, Fjellström, & Sidenvall, 2003). The anticipation of recovery is often associated with the ability to eat independently (Jacobsson, Axelsson, Österlind, & Norberg, 2000).

1.3 Summary

The evidence supported from the literature demonstrates a dire need for food specifically designed for our growing the elderly population. Their specific sensory losses should be addressed along with packaging solutions that allow this cohort to live independently for as long as possible. Malnutrition and the associated ailments along with safety risks related to packaging should be minimised. The elderly is the fastest growing population. Food industry should acknowledge this niche in the market and focus more on accommodating the elderly needs than the younger populations. Nutrition merits special consideration as people reach older age and is important for good health. Healthy ageing is linked with physiological, cognitive, social and lifestyle changes that impact dietary intakes and nutritional status. Health status is highly associated with the ageing process, and nutrition is one factor that has beneficial or negative effects on the rate of the ageing process (Stanner, 2009).

CHAPTER 2

Consumer attitudes towards meat in Ireland

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Abstract

Ireland has a thriving meat Industry. Meat and meat products are extremely important sources of nutrients and provides a unique nutritionally-dense food offering. This study examined consumers (n=1657) attitudes pertaining to meat and meat products in Ireland. The survey was based on demographic questions, such as; age group, gender, health status, income and education level. It was found that a huge lack of nutritional knowledge is evident among older consumers, who were not confident in answering questions relating to processed meat and health status. Processed meat consumption was higher in those with swallowing difficulties and with those who wore dentures. Middle income participants preferred processed meats presumably for their convenience in preparation. This study provides background information detailing Irish consumer's motives behind meat and processed meat consumption.

Key Words: Survey, Processed Meats, Consumers

2.1 Introduction

Ireland has a long-standing reputation as a country with a premium image for the manufacture of good quality fresh and processed meats. The continuous demand for ever higher standards of quality assurance in meat production, calls for the development of new tools capable of meeting such demands. Meat accounts for over 40.0% of Ireland’s gross agricultural output, dominated by beef, followed by pork and sheep meat. In 2016, Irish agri-food and drink exports increased by an estimated 2.0% to approximately €11.15 billion. The latest estimates of the distribution of our agri-food and drink exports in 2016 by sector are as follows: dairy products and ingredients (30.0%), beef (21.0%), prepared consumer foods (17.0%), beverages (13.0%), pigmeat (6.0%), seafood (5.0%), poultry (3.0%), sheepmeat (2.0%), edible horticulture & cereals (2.0%) and live animals (1.0%) (Bord Bia, 2017).

Total meat can be broken down into red meat (including beef, lamb, veal, pork, ostrich and venison), white meat (including chicken, turkey, duck and game fowl) and processed meat (including cured and smoked meats; ham, bacon, sausages, hamburgers, salami and tinned meat (Linseisen et al., 2002). Processed meat is often perceived by consumers as being unhealthy due to perceived levels of sodium, and fat (Tobin, O’Sullivan, Hamill, & Kerry, 2014). Currently in Ireland there is a huge focus on processed meats and their health effects. According to the Food Safety Authority of Ireland (FSAI), 19.0% of consumers stopped eating meat in the last few years due to concerns regarding food safety and 53.0% of consumers expressed concern regarding adverse long-term health effects from consumption of these products (Caulfield, 2003). The North and South Food Consumption Survey in Ireland provides a detailed account of the food consumption patterns in Ireland. However, little research has been conducted into the motives behind purchasing and consuming meat and meat products in Ireland. Research in consumer’s perceptions of meat and processed meat is limited. It is important to understand the motives and perceptions consumers have when purchasing and consuming meat and meat products. This information may be utilised in the planning of future population trends, for example, the growing population of those aged over 65 in Ireland. The old population (i.e. those aged 65 years and over) is projected to increase very significantly from its 2011 level of 532,000 to between 850,000-860,700 by 2026, and close to 1.4 million by 2046. The very old population (i.e. those aged 80 years of age and over) is set to rise even more dramatically, increasing from 128,000 in 2011 to between 484,000-470,000 in 2046 (CSO, 2016).

The survey conducted here set out to explore Irish consumer (n=1657) knowledge and attitudes pertaining to meat, meat products and meat packaging in Ireland over various age cohorts. The study sought to understand the motives behind consumer preferences for meat products from a health, age, income and education perspective.

2.2 Materials and methods

The survey was composed of 26 questions. It was specified that the consumers filling out the survey had to be regular consumers of meat products in Ireland. A survey was generated using Survey Monkey Software. A link was emailed and distributed using social media. The survey was also printed and posted to a wide cohort of the elderly subjects and various active retirement groups from around Ireland. All respondents represented the meat consuming population of Ireland. The ages of participants ranged from 18-85 years old. Both males and females took part. The survey was circulated online through University mailing lists and social media websites.

The start of the survey contained background information, such as; age, nationality, approximate annual income and highest level of education achieved. Age categories were as follows: 18-30, 31-40, 41-50, 51-65, 66-70, 71-80, 81-85 and 85+. Nationality options were

Irish and non-Irish. The approximate annual income fell under the following options: less than or equal to €10,000, less than or equal to €15,000, less than or equal to €20,000, less than or equal to €30,000, less than or equal to €40,000, less than or equal to €50,000 or greater than or equal to €51,000. Education levels were as follows; primary or secondary school, post leaving certificate course (PLC) or a level 6 FETAC course, third level course (FETAC level 7/8) or a postgraduate course (FETAC Level 9/10) as outlined by the Irish National Framework of Qualifications (NFQ).

Table 2.2 assessed the dental and health status of the respondents, and whether or not they preferred eating processed meat over fresh meat. The participants were asked if they ever avoided meat due to swallowing or chewing difficulties. They were asked if they wore dentures with the following options as responses; No, top or bottom, or both top and bottom. Respondents were also asked the following health questions; Do you suffer from high cholesterol?, do you suffer from hypertension?, do you suffer from type 1 diabetes, do you suffer from Type 2 diabetes. This list of health questions was derived from Health in Ireland Key Trends (2016). The most common health problems identified in Ireland were chosen for this study.

Consumers were asked to indicate on a scale from 1-10, the most common to the least common processed meats purchased, where 1=most common and 10 least common. Their options were as follows: sausages, rashers, puddings (both black and white), ham, corned beef, luncheon roll, burgers (chicken, lamb and beef), pulled pork and breaded meats such as chicken Kiev, chicken nuggets and chicken goujons (Fig 2.1).

The effects of age grouping on processed meat consumption, health status and preference was analysed (Table 2.3). The effects of income grouping on processed meat consumption, health status and preference was analysed (Table 2.4), and so too was the effects of education level grouping on processed meat consumption, health status and preference (Table 2.5). The effects of gender grouping on processed meat consumption, health status and preference was also analysed, however, this correlation showed no significant differences after statistical analysis.

2.3 Statistical analysis

The data obtained from the active retirement groups was inputted manually into an excel file and further analysed on SPSS. The online questionnaires from Survey Monkey were exported into a Microsoft Excel worksheet using Abode Reader converter and transferred into IBM SPSS Statistics 20. Data was summarised as frequencies for each question and presented in contingency tables. Significance was determined using Chi-square analysis, and when statistical differences occurred, a Chi square post-hoc test was utilised. A significance level of $P<0.05$ was set and this was adjusted to control type 1 error rates. The adjusted P value = 0.05/Number of analyses performed according to the methods outlined by Beasley & Schumacker (1995).

2.4 Results and discussion

A total of 1,657 complete responses were collected and analysed from the survey. The participant's demographic details are presented in Table 1. The majority of the participants surveyed were aged between 66-70 yrs. old (20.1%). This age cohort were sent surveys via the postal service. Younger people are more likely to participate than older people in surveys (Goyder, 1986; Moore & Tarnai, 2002). For this reason, surveys were sent as a hard copy to insure this age grouping had the opportunity to fill out the survey, irrespective of their ability to access or use computers.

The 51-65 age cohort were the poorest participating age group. The majority of the participants were of Irish nationality (87.5%). As this study was focused on meat consumption in Ireland, it was essential that other nationalities who regularly consumed meat in Ireland were included the majority of participants were female (72.9%). This figure was expected, as previous research found that females are more likely to partake in surveys than men (Curtin et al 2000; Moore & Tarnai, 2002; Singer et al. 2000). The majority of respondents earned less than, or equal to, €10,000 (35.1%). This figure may be due to the large student population that participated in the survey. Most participants had primary or secondary level education (37.8%) and third level education (36.7%). This figure again may reflect the large student population and also the large the elderly demographic. According to the Central Statistics Office (CSO), 56.2% of people aged 15 to 39 possesses a third level qualification in Ireland, in comparison to 18.9% of those aged 65 and over. The proportion for those aged 65 and over educated to primary level was only 39.7% (CSO, 2016).

Table 2.1: Demographic results of consumer

Age	**n**	**%**
18-30	207	12.4
31-40	194	12.4
41-50	130	11.6
51-65	335	7.8
66-70	215	20.1
71-80	241	12.9
81-85	125	14.4
85+	210	12.6
Irish		
Yes	1461	87.5
No	196	11.7
Gender		
Male	440	26.3
Female	1217	72.9
Approximate annual income		
≤ €10,000	586	35.1
≤ €15,000	204	12.2
≤ €20,000	340	20.4
≤ €30,000	229	13.7
≤ €40,000	125	7.5
≤ €50,000	49	2.9
≥€51,000	124	7.4
Highest level of education		
Primary/Secondary	632	37.8
Post Leaving Certificate	202	12.1
Third Level Course	613	36.7
Post Graduate Course	210	12.6

The weighted average of processed meat consumption of participants in this study is shown in Fig. 2.1. Sausages were the most commonly consumed processed meat product (n=532), followed by rashers (n=530) ham (n=529) and corned beef (n=526). Currently there is very little information regarding the consumption of processed meats in Ireland Similar results to those found here were observed in the North/South Food Consumption Survey where bacon and ham were shown to be the most commonly consumed meats (80%), followed by chicken (71.0%), sausages (59.0%), and beef (55.0%) (IUNA, 2001). The National Adult Nutrition Survey (NANS) 2008 – 2010 was conducted in the Republic of Ireland. It involved 1,500 participants aged 18 years and over. In this survey, different clusters based on demographics were observed. Those who consumed processed pork products comprised 13.0% of respondents, and derived the highest proportion of their energy intake (28.0%) from meat in their diet. They also had fat intakes above what is recommended for a healthy diet. The meat products most consumed were pork-based, with this segment consuming five-times more sausages/bacon/puddings than the other age-based segments. This segment was also characterised by a high proportion of men from a lower socio-economic background and who had little motivation to eat healthily. In contrast, the beef-focused cluster consumed the most beef and had a relatively low consumption of other meats. The gender-balanced, beef-focused segment had total fat intakes in line with healthy guidelines (IUNA, 2011). By understanding the most preferred processed meats consumed by Irish consumers, the motives behind purchasing these products can further understood. Taste, convenience and shelf-life are all positive associations affiliated with processed meat products.

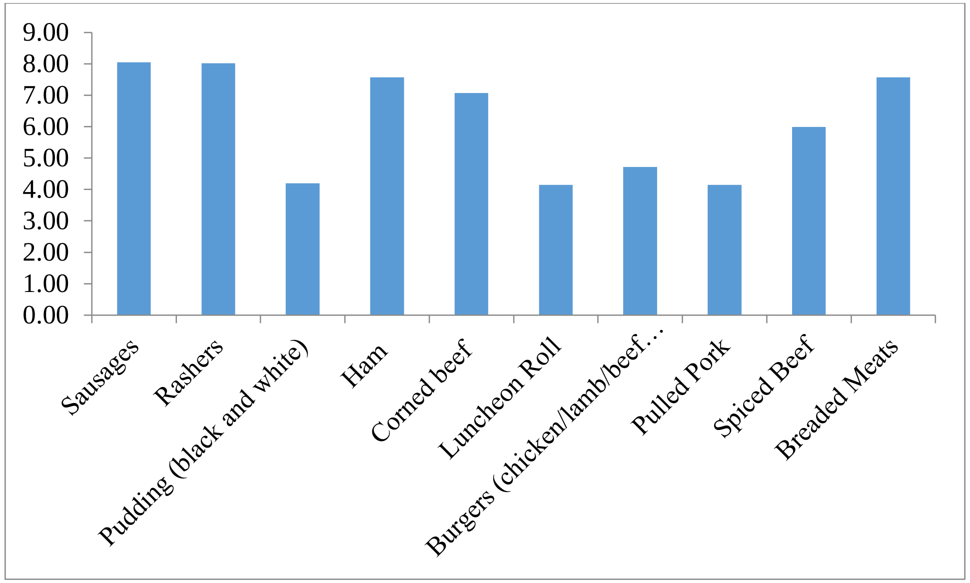

Figure 2.1: Weighted average consumption of processed meats

Table 2.2: Dental & health status effects on meat type preference

Do you prefer eating processed meats over fresh meats?	Do you ever avoid meat due to swallowing or chewing difficulties?		Do you wear dentures?			Do you suffer from high cholesterol?		Do you suffer from hypertension?		Do you suffer from type 1 diabetes?		Do you suffer from type 2 diabetes?	
	Yes	**No**	**No**	**Top or bottom**	**Top & bottom**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
Yes	$71.70^{0.006}$	$28.30^{0.000}$	74.50	70.80	$89.20^{0.000}$	$62.80^{0.004}$	$37.20^{0.003}$	65.40	34.60	68.80	31.30	$90.60^{0.000}$	$9.40^{0.05}$
No	$78.70^{0.000}$	$21.30^{0.002}$	$25.50^{0.000}$	29.20	$10.80^{0.000}$	$76.30^{0.000}$	23.70	$75.70^{0.000}$	24.30	75.60	24.40	74.50	$25.50^{0.000}$

Superscript values indicate where significance lies within each question

The influence age has on processed meat consumption, health status and preference is shown in Table 2.3. As observed, most of processed meat intake is consumed at lunch or supper, with the exception for those participants within the 18-30 and 51-65 age cohort, who consumed most of their processed meat intake at lunch or supper time. Processed meat is consumed as part of the main meal of the day (dinner) by most of the respondents. Large numbers of respondents, across all the age cohorts, stated that they were not properly informed to state whether they think processed meat is bad or not for their health. The following age categories had significant correlations for this statement: 31-40, 51-65, 71-80 and 85+.

Most of the youngest age cohort (18-30 yrs. old) significantly indicated that they thought processed meat was bad for their health (69.4%), whereas the oldest age cohort significantly indicated that they were not well informed on the matter to have an opinion (41.9%). As described previously, the younger age cohort was more educated than older age cohorts and this may play a part in health knowledge relating to nutrition. Nutrition education is an important measure to improve dietary habits and food choices, since poor dietary habits are the main reason for poor nutritional status. The WHO has advocated mass information and awareness programs to be organised to alert government and communities about the importance of health education (Gupta and Kochar, 2009). The future the elderly generation is likely to be more health-conscious and better educated therefore, more innovative approaches to nutrition education will be needed to keep pace with these changes Alexander, Lindberg, Firemark, Rukstalis, & McMullen (2018).

Those who prefer eating processed meats over fresh meats were significantly more likely to have swallowing difficulties (71.7%) than those who had no swallowing difficulties (28.3%). These participants were more likely to wear dentures, with 89.2% of participants who preferred eating processed meats over fresh meats also possessing both top and bottom dentures. Nutrition in older consumers is hugely effected by reduced masticatory ability. For example, fewer teeth can result in the swallowing of a coarser bolus. Deterioration in masticatory function (compromised function which may occur with dentures) can lead consumers away from foods considered difficult to chew in favour of softer, more easily chewed foods (Chauncey, Muench, Kapur & Wayler, 1984; Heath, 1982).

In recent years, processed meats are more in the public eye for being carriers of fat and salt. However, in this study the majority of those who expressly did not prefer eating processed meats over fresh meats suffered from either high cholesterol (62.8%), hypertension (75.7%) or type 1 diabetes (75.6%). Therefore, it is important based on these findings that processed meats are not unfairly labelled or targeted as bad products, but rather, be viewed products which contain ingredient components like salt and fat which have a negative nutritional impact and consequently, need adjustment.

According to IUNA (2001), meat and meat products account for 37.0% of the Irish protein intake, with 70.0% of consumers eating meat products. According to IUNA (2011), 47.0% who consume meat products are aged 18-64 (n=1274) and 30.0% of processed meat consumers are aged over 65 yrs. old (n=226). Mean daily intakes of salt estimated from the sodium content of foods consumed, exceeded FSAI salt intake targets (6g/day). Among 18-64 year olds, the mean daily intake of salt was 7.4g, with men (8.5g) having higher intakes than women (6.2g). Adults aged 65 years and over had a mean daily salt intake of 6.3g, with men (7.3g) having higher intakes than women (5.4g). The main contributors to salt intakes in the population were determined as being cereals and breads, and cured and processed meats. In 2005, the FSAI suggested in its "Salt and Health" report that an attainable salt intake target for the Irish population was 6g salt per/day (2.4g sodium). Currently the World Health Organisation (WHO) recommends a daily intake of 5g salt per/day for adults. Recent estimates of salt intake for the Irish population provided through the "National Adult Nutrition Survey" indicates that among 18-64 year olds, mean daily intakes of salt from processed foods are 7.4g, with men (8.5g) having higher intakes than women (6.2g). Adults aged 65 years and over have an estimated mean daily salt intake of 6.3g, with men (7.3g) having higher intakes than women (5.4g). Since 2003, the Food Safety Authority of Ireland (FSAI) has coordinated a salt-reduction programme working in partnership with the food industry, Food and Drink Industry Ireland (FDII), Retail Ireland, various State bodies and educational organisations to achieve voluntary, gradual and sustained reductions in the salt content of processed foods. Many other countries have also implemented similar salt-reduction programmes.

Data from NANS (2011) demonstrated that a 0.35g/day decrease in salt intake because of cured and processed meat products (1.68g/d) to (1.33g/d). This may be due to public health interventions targeting salt reduction and salt reduction interventions such as the FSAI salt reduction programme. Over a ten-year period, the FSAI were successful in decreasing average salt content of many processed foods, including processed meats, so that the mean daily/intake from processed foods decreased by 1.1g. Additionally this improved consumer choice and also improved labelling of salt on consumer products (McDonald, 2013).

Significant results observed from Table 2.3 indicate that a larger number of younger subjects prefer processed meat over fresh meat, where 83.5% of those aged 18-30 said they preferred processed meats, whereas only 45.2% of those aged between 71-80 said that they preferred processed meats over fresh meat. Much of the association between education and health is brought about by the positive effect of education on job opportunities, annual income, housing, access to nutritious foods and health insurance (Smith, Hart, Hole, MacKinnon, Gillis, Watt, & Hawthorne, 1998).

Table 2.3: Age effects on processed meat consumption, health status and preference

	Age group (yrs. old)								
	18-30	**31-40**	**41-50**	**51-65**	**66-70**	**71-80**	**81-85**	**85+**	***P* value**
What meal do you consume most of your processed meat intake									
Breakfast	27.67 ^{ns}	22.16 $^{0.00128}$	20.00^{ns}	29.55 ^{ns}	26.05 ^{ns}	25.31 ^{ns}	23.20 ^{ns}	21.43 ^{ns}	0.003
Lunch/Supper	30.10 ^{ns}	50.52 $^{0.00221}$	49.23 ^{ns}	32.84 $^{0.00158}$	39.07 ^{ns}	46.06 ^{ns}	38.40 ^{ns}	43.81 ^{ns}	
Dinner	42.23 ^{ns}	27.32	30.77 ^{ns}	37.61 ^{ns}	34.88 ^{ns}	28.63 ^{ns}	38.40 ^{ns}	34.76 ^{ns}	
Do you think processed meat is bad for your health?									
Yes	69.42 $^{0.002}$	82.47 $^{0.000}$	70.00	54.03 ^{ns}	69.77 $^{0.00104}$	27.80 $^{0.000}$	71.20 ^{ns}	50.00 ^{ns}	0.002
No	13.59 ^{ns}	5.15 $^{0.000}$	12.31	14.33 ^{ns}	8.84 $^{0.00005}$	68.88 $^{0.000}$	8.00 $^{0.00115}$	8.1 $^{0.00002}$	
Not properly informed	16.99 ^{ns}	12.37 $^{0.001}$	17.69	31.64 $^{0.000}$	21.40 ^{ns}	3.32 $^{0.000}$	20.80 ^{ns}	41.90 $^{0.000}$	
Do you prefer processed meat over fresh meat?									
Yes	83.50 $^{0.00451}$	79.38 ^{ns}	86.92 $^{0.00169}$	74.03 ^{ns}	75.35 ^{ns}	45.23 $^{0.000}$	83.20 ^{ns}	90.00 $^{0.000}$	0.004
No	16.50 $^{0.00451}$	20.62 ^{ns}	13.08 $^{0.00169}$	25.97 ^{ns}	24.65 ^{ns}	54.77 $^{0.000}$	16.80 ^{ns}	10.00 $^{0.000}$	

P represents level of significance within a group. Superscript values indicate where significance lies within each question and column

Many factors such as wealth, volume of livestock production and socio-economic status of consumers could explain the higher consumption pattern of meat by western populations (Mann, 2000). As observed from Table 2.4, the majority of the two highest income levels <€50,000 and €51,000 both significantly stated that they did not think that processed meats were bad for their health and that they consumed fresh meat over processed meat. This result was in line with data from a FSA, 2012 report on the diet of low-income groups in Europe which indicated that there was a higher consumption of processed meats among economically disadvantaged groups compared to higher-income groups (FSA, 2012).

One powerful determinant of choice in food is cost, and this is likely to play a role in driving processed meat intake, as it is often cheaper to the consumer than lean ‘carcass’ meat. Cost has also been shown to be a factor inhibiting economically disadvantaged groups from accessing health and sustainable diets in other research (Barosh, Friel, Engelhardt, & Chan, 2014).

In a study carried out by Whichelow and Prevost (1996), dietary behaviour was divided into four sections, one of which was associated with high intakes of fruit and vegetables, high-fibre foods and low-fat spreads and milk. This section (the one which most closely meets current dietary recommendations) was favoured among those in the middle-age group, rather than the very old or very young age groups. It was also associated with socio-economic status, being most popular with the professional group. When the sample was divided into manual and non-manual careers, women from each group scored higher on this component than men of the same socio-economic status. In a follow-up study of the same sample seven years later, there was a significant increase in scores for the healthy diet component. However, non-manual responders showed significantly greater health-related improvements than those with manual occupations, indicating that differences in diet across socio-economic groups are continuing. A joint Texas A&M and Cornell University study estimated that a 10.0% increase in income is associated with a 0.7% increase in demand for ready-to-eat meals (USDA/ERS, 2002). The convenience associated with processed meats may be an underlying reason why those in middle income categories <€20,0000, <€30,000 and <€40,000 prefer processed meat over fresh meat. Multi-income households, for example, will not pay as much for fresh beef because of the time required in preparation. In general, consumers do little planning of meals (National Cattleman's Beef Association, 2002).

Those with the least formal education stated that they thought that processed meat was bad for health (primary/secondary school). In contrast, those with a PLC or a FETAC level 6 stated that they did not think processed meat was bad for their health (42.6%). It is interesting to note that the higher level of those educated felt that they were not properly informed to state whether or not they thought that processed meat was bad for health. Those with a FETAC level 7/8 (17.5%) significantly stated that they were not informed on the matter. However, irrespective of education level, processed meats were preferred by all education groups.

Table 2.4: Income effects on processed meat consumption, health status and preference

Annual Average Income	**<€10,000**	**<€15,000**	**<€20,000**	**<€30,000**	**<€40,000**	**<€50,000**	**>€51,000**	***P* value**
What meal do you consume most of your processed meat intake								
Breakfast	27.65	25.00	22.65	23.58	18.55	18.37	32.26 $^{0.05613}$	0.05
Lunch/Supper	34.64 $^{0.00042}$	43.14	42.06	41.05	42.74	63.27 $^{0.00093}$	45.97	
Dinner	37.71	31.86	35.29	35.37	38.71	18.37 $^{0.01595}$	21.77 $^{0.00194}$	
Do you think processed meat is bad for your health?								
Yes	66.21 $^{0.00004}$	64.71	66.76 $^{0.00237}$	57.64	58.87	30.61 $^{0.00003}$	15.32 $^{0.000}$	0.002
No	14.16 $^{0.00022}$	13.73	12.94 $^{0.00147}$	17.03	16.13	57.14 $^{0.0000}$	58.06 $^{0.000}$	
Not properly informed	19.62	21.57	20.29	25.33	25.00	12.24	26.61	
Do you prefer processed meat over fresh meat?								
Yes	77.30	77.45	85.00 $^{0.0001}$	79.04	87.90 $^{0.00087}$	42.86 $^{0.000}$	32.26 $^{0.000}$	0.004
No	22.70	22.55	15.00 $^{0.0001}$	20.96	12.10 $^{0.00087}$	57.14 $^{0.000}$	67.74 $^{0.000}$	

P represents level of significance within a group. Superscript values indicate where significance lies between eacg question and column

Table 2.5: Education level effects on processed meat consumption, health status and preference

	Primary/Secondary School	PLC/Level 6	Level 7/8	Level 9/10	*P* value
What meal do you consume most of your processed meat intake					
Breakfast	27.53	20.79	23.82	25.84	ns
Lunch/Supper	37.50	45.54	43.23	35.89	
Dinner	34.97	33.66	32.95	38.28	
Do you think processed meat is bad for your health?					
Yes	$53.64^{0.00012}$	$38.12^{0.000}$	$72.27^{0.000}$	60.77	0.004
No	20.41	$42.57^{0.000}$	$10.28^{0.000}$	17.22	
Not properly informed	$25.95^{0.00054}$	19.31	$17.46^{0.00214}$	22.01	
Do you prefer processed meat over fresh meat?					
Yes	$80.38^{0.00032}$	$56.44^{0.000}$	76.84	75.60	0.006
No	$19.62^{0.00032}$	$43.56^{0.000}$	23.16	24.40	

P represents level of significance within a group. Superscript values indicate where significance lies between each question and column. PLC = Post Leaving Certificate, Level 6, 7 & 8 established through the FETAC system

2.5 Conclusion

Consumer awareness of health associations with processed meats varied greatly. Willingness to consume products was not effected by knowledge of the subject. Clearly, a lot of confusion appears to exist among Irish consumers and the perceived effect that processed meats have on their health. The older age cohorts, with less education than the younger age cohorts, felt they lacked the correct information regarding processed meats and health status. It is clear that greater focus from the government needs to be put into place regarding nutrition education. Many of the participants in this survey felt they were unable to answer questions based on their health status as they felt they did not have enough knowledge on the topic.

Currently nutrition education in our country is developing at a great rate for the younger members of society through school interventions, however, this approach neglects educating our older society members. The preference for processed meat over fresh meat was dependent on different factors through different life stages, for example: Those with middle income preferred processed meat presumably due to its convenience while those with swallowing difficulties and those who wore dentures preferred processed meat. This information is very interesting as it could be manipulated into using these meat products as encouraging protein sources into the diets of malnourished the elderly following nutritional improvement in product formulations.

CHAPTER 3

Sensory capability of young, middle-aged and the elderly Irish assessors to identify beef steaks of varying texture

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Abstract

This study assessed the capability of various Irish assessor age cohorts to identify beef steaks of varying texture. Varying steak textures Moderately Tough (M_{TH}), Moderately Tender (M_{TR}) and Tender (T_R) were achieved by aging beef longissimus thoracis et lumborum (LTL) muscle for 2, 7 and 21 days respectively. Warner Bratzler Shear Force (WBSF) was measured to standardise the samples. Sensory evaluation was carried using 428 participants; 18–30 yrs. (years) (n = 143), 31–60 yrs. (n = 80), 61–75 yrs. (n = 99) and 76–85 yrs. old (n = 106). Within 6 age cohort categories (18–70), significant positive and negative correlations were observed for T_R and M_{TH} tenderness categories respectively. Poor identification of tenderness classification was found in the 71–85 age cohort groupings. Consequently, more research is required in this area so that guidelines could be presented for industrial uptake. This study supports the hypothesis that changes in textural perception occur with age in humans.

Keywords: Texture, The elderly, Sensory decline, Meat avoidance

3.1. Introduction

The term 'the elderly' has been defined as a chronological age of 65 years old or older, while those aged between 65 and 74 years old are referred to as ‘early the elderly’ and those over 75 years old are termed ‘late the elderly’ (Orimo et al., 2006). Older persons aged 65 and over accounted for 18.9% of the European Union (EU) population in 2010. This was an increase of 0.4% from the previous year and the previous ten years of 2.3%. It is expected that those aged 65 years and over will account for 28.7% of the EU population by 2080 (Giannakouris, 2008). The over sixty five age cohort saw the largest increase in population from 2011 to 2016 in the Irish census; rising by 102,174 to 637,567, a rise of 19.1%. The census recorded 456 centenarians, an increase of 17.2% on 2011. (CSO, 2016). The aged population is predicted to increase further by 2041; the number of people aged 75 and over in Ireland is estimated to reach almost 1 million. The number of Irish 85 + year olds is predicted to increase from the 2006 figure of 74,000 to 356,000 by 2041 (CSO, 2016). With this forthcoming increase in the elderly population, great economic challenges are anticipated, in addition to the enormous pressures that will be exerted on healthcare facilities and associated services.

High protein diets continue to gain scientific interest in their ability to preserve lean mass, promote weight loss, and prevent weight regain following weight loss or to maintain a healthy weight throughout the lifespan (Paddon-Jones & Leidy, 2014). A collection of data from muscle protein anabolism, appetite regulation and satiety studies suggests meeting a protein threshold of approximately 30g/meal. This represents a strategy for middle-aged and older adults concerned with sustaining muscle mass while controlling body fat (Paddon-Jones & Rasmussen, 2010; Arciero et al., 2013). Currently in Ireland, 37% of the population's protein intake is obtained from meat and meat products (IUNA, 2001). Thus, it is in the Irish beef industries best interest to ensure all of the populations textural preferences are catered for. Evaluation of texture is a complex and dynamic process that includes visual perception of the surface of the product, product behaviour in response to previous handling and integration of in-mouth sensations experienced during mastication and further swallowing. Texture evaluation should be carried out by a sensory panellist, as it determines the sensation perceived by the panellist when consuming the product. As chewing and swallowing occurs, texture-related sensations are perceived, along with taste and flavour (Stokes, Boehm, & Baier, 2013). For the elderly who are unable to swallow due to dysphagia, declining sensory perception and saliva production, a decrease in food pleasantness may be perceived (Finkelstein & Schiffman, 1999). Unfortunately, an indifference to consuming meat, and indeed other food products, will result in various malnutrition forms which will subsequently lead to various life-limiting diseases. Beef is a muscle food whereby texture plays an important sensory characteristic. Meat quality is a complex term involving many attributes including; colour, texture and flavour. Tenderness is viewed as the most important characteristic associated with beef palatability (Jaramillo, 1994; Miller, Carr, Ramsey, Crockett, & Hoover, 2001; Smith, Tatum, Belk, & Scanga, 2008). While this is understood, little is known with regard to how the meat quality parameter is defined in respect to consumer classification. What is known is that by improving tenderness, consumer's acceptance for muscle foods increase (Campo et al., 2000). Many studies examining the relationships between muscle aging on instrumental texture and sensory assessments have been highlighted in a review carried out by Muchenje et al. (2009). The review demonstrates the ranges of sensory scores for some meat quality characteristics (aged for 2–21 days) as reported in the literature. It was found that sensory values for tenderness tend to be high as the aging times increase. Muchenje et al., (2009) reported that the important meat quality characteristics are indeed tenderness, flavour and colour and they concluded that factors affecting meat eating quality include improving the body condition of animals before slaughter, reducing pre-slaughter stress, aging meat correctly, and developing appropriate feeding management strategies.

There are many studies comparing sensory characteristics between the elderly and younger consumers, whereby deterioration in the senses was noted as humans aged. Mojet (2003) studied various taste perceptions and their effects on human aging. NaCl, KCl, sucrose, aspartame, acetic acid, citric acid, caffeine, quinine, hydrochloric acid (HCl), monosodium glutamate (MSG) and inosine 5′ monophosphate (IMP) were dissolved in water and food products. Participants ranged in age from 19 to 75 years (n = 42). It was found that the intensity rating decreased with age for all tastants in water, but only for the salty and sweet tastants in products. Yoshinaka et al. (2015) investigated three age groups for taste sensitivity. The ages ranged from 24 to 71 years (n = 2015). Recognition thresholds for the four basic tastes were measured using a whole mouth gustatory test. The authors concluded that there are age differences in sensitivity between various age groups. To date, most research has focused on the flavour differences in foods as perceived by different age cohorts. Oral perception decline, olfactory perception decline, badly fitting dentures, medications, social and socio – economic factors all play a role in meat avoidance in the elderly. However, relatively little is known about the effects that consumer aging has on meat textural preferences.

The main objectives of this study are as follows:

1. Determine the influence texture has on sensory properties of steak

2. Study the perception of tenderness in different age populations

3. Determine if differences in liking could affect beef consumption habits of the elderly in Ireland.

3.2. Materials and methods

3.2.1. Sample preparation

Beef longissimus thoracis et lumborum (LTL) muscle was purchased from a local abattoir; Ballyburden Meats, Ballincollig, Co Cork. The animals all featured the following euro grades; E, R, 3. All animals were the same breed; Limousin, the same age at slaughter; 2 years old and the same sex; female. Six primals (striploin) were purchased from three animals. The six primals were dry aged in the abattoir at a constant humidity of (80%) prior to delivery. All primals were subsequently cut into sub-primal pieces (steaks) (25.4mm x 5.4mm). All steaks were pooled and randomly assigned to one of the three wet aging periods; 2, 7, or 21 days (M_{TH}, M_{TR}, $T_{R)}$ respectively. The steaks were aged in sealed vacuum bags (Vacuum pouch PA/PE 90 Niederwiser) ($O_{2:}$ 50 cm^3/m^2/24 h/bar, N_2: 10 cm^3/m^2/24 h/bar, $CO_{2:}$ M150 cm^3/m^2/24 h/bar) at 4 °C. The steaks were then labelled and vacuum packed. These packs were then blast frozen (Foster, Mod BF35, Norfolk, UK) and stored at −18 °C until the steaks were required. Upon requirement, steaks were defrosted at 4 °C for 24 h prior to cooking. Triplicate measurements were carried out on the three individual steaks at each aging time. All steaks used for sensory assessment were also analysed for physical and chemical analysis. All analyses (proximate and physiochemical) was carried out three times on triplicate steaks from each treatment: M_{TH}, M_{TR}, T_R.

3.2.2. Cooking

Oven cooking of the steaks was chosen as the cooking method as it was deemed to be a relatively easy cooking approach, provided consistent results and was easily replicated. All steak samples were wrapped in aluminium foil, labelled and dry-cooked at 150 °C in a Zanussi convection oven (C. Batassi, Conegliano, Italy) for 20min to an internal temperature of 73°C, as measured by a temperature probe (Testo 110, Lenzkirch. Germany).

3.2.3. Proximate compositional analysis

3.2.3.1. Protein content

The Kjeldahl method, with slight modifications was used to determine the protein in steak samples (Suhre, Corrao,Glover, & Malanoski, 1982), and percentage protein was calculated using a nitrogen conversion factor of 6.25. This method was in accordance with the work outlined by Tobin, O'Sullivan, Hamill, and Kerry (2013).

3.2.3.2. Ash content

The ash content of was determined gravimetrically using a furnace at 550 °C (Nabertherm GmbH, Lilienthal, Germany) AOAC., (1996) method 920.153.

3.2.3.3. Moisture & fat content

A SMART Trac system (CEM GmbH, Kamp-Lintfort, Germany) was used to measure the percentage moisture and fat. Approximately 1.0g of each of the homogenised vacuum packed steak samples were measured in accordance with the methods used by Bostian, Fish, and Webb (1985).

3.2.3.4. Carbohydrates

Total carbohydrates were determined by difference: A hundred grams minus the addition of protein, fat, water and ash in grams, expressed as a percentage.

3.2.4. Sensory analysis

3.2.4.1. Recruitment

Panellists of varying age cohorts were recruited for this study. Panellists were chosen in compliance with the following criteria; community dwelling, healthy, not on a pre-described diet, did not have a food allergy, did not have any difficulties swallowing, and were regular consumers of beef steak. The subjects were recruited from University College Cork and from active retirement groups based around the Cork region. The assessor cohorts were derived from various socio-economic backgrounds and were gender balanced. The panellists completed a questionnaire prior to participating in the sensory evaluation. They included their annual income by ticking a box from the following options; ≤€20,000, €20,000 – €50,000 or ≥ €50,000. The elderly participants completed a questionnaire indicating if they had a medical card or not. Recruitment was divided equally around these socioeconomic factors. All participants indicated their gender in the questionnaire. They also signed a declaration indicating they did not have any difficulties swallowing food.

3.2.4.2. Sensory evaluation

Sensory analysis was carried out on 428 participants. Ages ranged from 18 to 85 years and categories ranged as follows; 18–30 (n = 143), 31–60 (n = 80), 61–75 (n = 99), 76–85 (n = 106). The age categories were subdivided into 9 age cohorts; 18–30, 31–40, 41–50, 51–60, 61–65, 66–70, 71–75, 76–80 & 81–85. Sensory analysis was carried out in the sensory kitchen in University College Cork. The kitchen features sensory booths and conforms to (ISO, 1998) standards. The samples were assigned random three digit codes. Sensory analysis was also carried out on triplicate batches presented to the panellists in duplicate. Assessors were asked to rinse their mouths with water in between each sample. The panellists were asked to rate the coded and randomised order samples using a hedonic eight-point scale (AMSA, 1995). The following attributes were assessed: tenderness, overall flavour, overall firmness, overall texture and overall acceptability (AMSA, 1995).

3.2.5. Physical analysis

3.2.5.1. Texture analysis

Texture profile analysis (TPA) was used to determine the texture of the samples instrumentally. All samples (cooked) were analysed in triplicate, using a Texture Analyser 16 TA-XT2i (Stable Micro Systems, Godalming, U.K). Three individual (10mm x 10mm) cylindrical slices (cores) of steak were taken from each sample and a duplicate sample. The steak cores then underwent a two–cycle compression test using a 25kg load cell. The samples were compressed using a 35mm diameter cylindrical probe (SMSP/35 Compression plate). A cross–head speed of 1.5mm/s was employed. The deformation percentage employed for this experiment was 50%. The texture profile descriptors measured included the following: Hardness (N) - represents the maximum force required to compress the steak at the first bite, springiness (mm) – represents the ability of the sample to return to its original state after deformation, adhesiveness (N x mm) represents the part under abscissa, post initial compression, chewiness (N) – represents the work required to masticate the steak to a state that can be swallowed, resilience (dimensionless) – represents the ratio of work carried out between the negative and positive force input during the first compression and cohesiveness (dimensionless) represents the ratio of work carried out between compressions.

3.2.5.2. Warner–Bratzler Shear Force

Shear force was measured according to the methods of Shackelford, Morgan, Cross, and Savell (1991). Each steak was placed in an individual plastic bag and sealed. It was then placed in a water bath (Model B21, Fisher Scientific GmnH, Schwerte, Germany). Steaks were cooked to an internal temperature of 75 °C and refrigerated overnight at a temperature of 4.4 °C. Ten core samples were obtained from each steak. Three steaks from each treatment were analysed. They were cored (n = 10) parallel to the muscle fibre direction. Warner-Bratzler Shear Force (WBSF) was measured using a T Analyser Stable Micro Systems testing machine with a Warner Bratzler V shaped shearing device (Stable Micro Systems, England). The crosshead speed was 4mm/s. Results were expressed as maximum shearing force/kg diameter core. The six closest samples to the mean were utilised as recommended by the experimental procedure. WBSF was used to standardise the samples prior to sensory testing.

3.2.5.3. Cooking loss analysis

The samples were placed on aluminium plates and their initial weight was recorded. After cooking the samples were allowed to cool down at room temperate for approximately 20min and then reweighed. Cooking loss was determined as the difference between cooked and raw weights expressed as a percentage of the raw weight.

3.2.6. Statistical analysis

All analyses (proximate and physiochemical) was carried out three times on triplicate steaks from each treatment: (M_{TH}) (M_{TR}) and (T_R). One-way ANOVA was used to examine the data from instrumental analysis and compositional analysis. Tukey's post hoc test was used to adjust for multiple comparisons between treatment means using SPSS statistics 20 software (IBM, Armonk, NY, USA). Data was presented as mean values ± standard deviation. Sensory was also carried out on triplicate batches presented to the panellists in duplicate. The data obtained from the sensory trials and the data obtained from the instrumental analysis was analysed using Unscrambler software version 10.3 (CAMO ASA, Trondheim, Norway). Data was processed using ANOVA–Partial Least Squares Regression (APLSR). The X-matrix was designed as different age categories and treatments. The Y–matrix was the sensory and instrumental variables. The optimal number of constituents in the APLSR models presented was concluded to be PC1 vs PC2. The APLSR model can be seen in Fig. 3.1.

3.3. Results and discussion

The range of values for compositional analysis can be seen in Table 1 and they are as follows: Protein 28.8–29.0%, fat 6.6–7.0%, moisture 62.2–62.7%, ash 1.3–1.4%, carbohydrates 0.3–0.6%, and cook loss 24.5–24.6%. There were no significant differences observed in the proximal compositional analysis of the steaks. These results were as expected as the composition of the beef steaks was not altered.

Results obtained for WBSF testing differed and the results are presented in Table 3.2. Values obtained for the varying treatments were as follows: sample MTH (6.6 ±0.14), M_{TR} (5.0 ±0.48) and T_R (4.2 ± 0.19). Similar observations were noted previously by other researchers (Lorenzen, Neely, Miller, & Tatum, 1999) and (Boleman et al., 1997), where aging of striploins improved WBSF results.

The TPA values are also presented in Table 3.2. Hardness (N), Springiness (mm), Chewiness (N), Resilience (dimensionless) all featured varying significant results between the three treatment groups. As hardness is the main factor deciding the commercial value of meat Chambers & Bowers, (1993), it was important that hardness varied in the samples to assess the varying age cohort's value of commercial appeal and worth of the steak samples.

Results from assessor sensory evaluations are presented in the APLSR plot (Fig. 3.1). The corresponding *P* values for regression coefficients are presented in Table 3.3. The attributes associated with overall acceptability were tenderness, flavour, and texture. Firmness may have had a lesser part to play in overall acceptability. The results presented above showed six age cohorts categories aged between 18 and 60 years old, were capable of detecting at least one attribute difference in steak samples from either the 21-day (T_r) or the 2 day aging treatment (M_{TH}) treatment group employed in this study.

Table 3.1

Proximal compositional analysis and cook loss values for beef longissimus thoracis et lumborum (LTL) muscle wet aged for 2 days (Moderately Tough, M_{TH}), 7 days (Moderately Tender, M_{TR}) and 21 days (Tender, T_R) at 4 °C.

Sample	Protein (%)	Fat (%)	Moisture (%)	Ash (%)	Carbohydrates (%)	Cook loss (%)
M_{TH}	29.0 ± 0.42[a]	6.6 ± 0.32[a]	62.7 ± 0.99[a]	1.3 ± 0.25[a]	0.3 ± 0.44[a]	24.5 ± 0.34[a]
M_{TR}	28.9 ± 0.13[a]	7.0 ± 0.21[a]	62.2 ± 0.66[a]	1.4 ± 0.24[a]	0.5 ± 0.59[a]	24.5 ± 0.31[a]
T_R	28.8 ± 0.45[a]	6.6 ± 0.58[a]	62.2 ± 1.30[a]	1.4 ± 0.33[a]	0.6 ± 0.38[a]	24.6 ± 0.20[a]

[abc]Mean values (± standard deviation) in the same column bearing different superscripts are significantly different, $P \leq 0.05$.

Table 3.2

Warner-Bratzler Shear Force (WBSF) and texture profile analysis (TPA) values for beef longissimus thoracis et lumborum (LTL) muscle wet aged for 2 days (Moderately Tough, M_{TH}), 7 days (Moderately Tender, M_{TR}) and 21 days (Tender, T_R) days at 4 °C.

		TPA				
Sample	**WBSF (kg)**	**Hardness (N)**	**Springiness (mm)**	**Adhesiveness (N × mm)**	**Chewiness (N)**	**Resilience (n/a)**◆
M_{TH}	6.6 ± 0.14[a]	140.13 ± 0.22[a]	0.5 ± 0.02[a]	– 0.4 ± 0.1[a]	57.5 ± 0.40[a]	0.2 ± 0.02[a]
M_{TR}	5.0 ± 0.48[b]	122.18 ± 0.23[b]	0.6 ± 0.03[b]	–1.40 ± 0.3[b]	46.0 ± 0.56[b]	0.1 ± 0.01[b]
T_R	4.2 ± 0.19[c]	98.7 ± 0.52[c]	0.7 ± 0.04[c]	– 0.02 ± 0.02[a]	36.6 ± 0.34[c]	0.2 ± 0.01[c]

[abc]Mean values (± standard deviation) in the same column bearing different superscripts are significantly different, $P \leq 0.05$.

◆ (n/a) resilience measurement is dimensionless.

The 18–30 age cohort were significantly ($P \leq 0.05$) negatively correlated to the 2-day aging treatment (M_{TH}) for overall acceptability. It was also significantly ($P \leq 0.001$) negatively correlated for flavour. This age category also significantly ($P \leq 0.01$) negatively correlated the 7-day (M_{TR}) aging treatment for flavour. The 31–40 age cohort were significantly ($P \leq 0.001$) positively correlated for the 21-day (T_R) aging treatment for overall acceptability. This sample was significantly and positively correlated for tenderness ($P \leq 0.001$), flavour ($P \leq 0.001$), firmness ($P \leq 0.05$) and texture ($P \leq 0.001$). This age category also significantly ($P \leq 0.05$) negatively correlated sample M_{TH} for overall flavour. The 41–50 age cohort significantly ($P \leq 0.05$) negatively scored overall acceptability for sample M_{TH}. This age category also significantly ($P \leq 0.05$) negatively scored this sample for tenderness, flavour and texture. The 51–60 age cohort significantly ($P \leq 0.05$) positively scored sample T_R for overall acceptability. This age category also significantly ($P \leq 0.01$) positively scored this sample for tenderness.

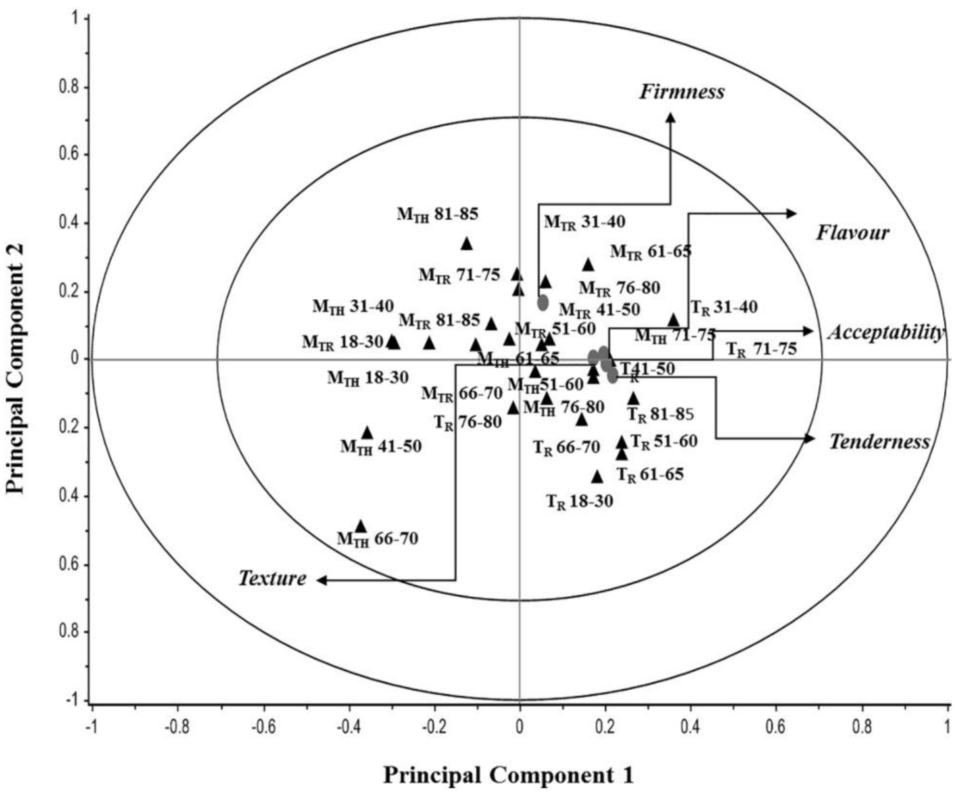

Fig 3.1. ANOVA - partial least squares regression (APLSR) correlation loading plot for each individual treatment, age category and sensory descriptor

An overview of the loadings of the X and Y variables for the first two PCs for the individual treatments and age categories V's sensory descriptors.

Treatment: Moderately Tough (M_{TH}) Moderately Tender (M_{TR}) and Tender (T_R) and age categories: 18–30, 31–40, 41–50, 51–60, 61–65, 66–70, 71–75, 76–80, 81–85 yrs. old ▲ Sensory descriptors ●

The 61–65 age cohort significantly ($P \leq 0.05$) positively correlated sample T_R to overall acceptability. This sample was also significantly ($P \leq 0.05$) and ($P \leq 0.01$) positively correlated for texture and tenderness, respectively. Age-related textural differences were observed in younger assessors compared to that of the elderly cohort in this study. This has been previously shown by other authors for non-meat food products. For example, textural changes were shown to have a higher degree of pleasantness for the elderly assessors when compared to younger test subjects when muesli products were evaluated (Kälviäinen, Salovaara, & Tuorila, 2002). Pleasantness was rated as lower by the elderly subjects, compared to younger assessors, when both were presented with texturally-modified yoghurts (Kälviäinen, Roininen, & Tuorila, 2003). Age-related textural differences were identified in soups and it was shown that the elderly and younger panel subjects differed in their texture–flavour interaction effects when soups were prepared with or without potato starch, with or without mushroom flavour and with water or with milk (Kremer, Mojet, & Kroeze, 2005). In another study examining the various textural preferences for carrots, it was determined that the young adults liked difficult textures such as rough, crispy, crunchy and hard to a far greater degree than the elderly respondents, but interestingly, the softer textures were not liked by either age group (Roininen, Fillion, Laurence Kilcast, & Lahteenmaki, 2003). The 66–70 age cohort significantly ($P \leq 0.01$) negatively correlated T_R samples for overall acceptability. It was significantly and negatively correlated for tenderness ($P \leq 0.05$), flavour ($P \leq 0.01$), firmness ($P \leq 0.001$) and texture ($P \leq 0.05$). Fig. 3.1 also displays the correlations of unacceptability for T_R samples by most assessors contained across all age categories. This can be observed in the left quadrant of Fig. 3.1.

Table 3.3

Significance of estimated regression coefficients (ANOVA values) for the relationship of sensory terms as derived by Jack – knife uncertainty tests for varying textures in different age cohorts

Sample[4]	Age cohort (yrs old)	Tenderness[1]	Flavour[1]	Firmness[1]	Texture[1]	Acceptability[1]
M_{TH}	18–30[5]	–0.09[ns2,3]	- 0.00[***]	– 0.66[ns]	– 0.14[ns]	- 0.04[*]
M_{TR}	18–30	– 0.10[ns]	- 0.01[**]	– 0.68[ns]	– 0.20[ns]	- 0.07[ns]
T_R	18–30	0.06[ns]	0.23 ns	0.09[ns]	0.29[ns]	0.15[ns]
M_{TH}	31–40	– 0.21[ns]	- 0.04[*]	– 0.85[ns]	– 0.22[ns]	- 0.13[ns]
M_{TR}	31–40	0.72[ns]	0.88 ns	0.09 [ns]	0.89[ns]	0.88[ns]
T_R	31–40	0.00[***]	0.00[***]	0.04[*]	0.00[***]	0.00[***]
M_{TH}	41–50	– 0.02[*]	- 0.02[*]	– 0.13[ns]	– 0.02[*]	- 0.02[*]
M_{TR}	41–50	0.71 [ns]	0.15[ns]	0.83[ns]	0.64[ns]	0.45[ns]
T_R	41–50	0.08 [ns]	0.28[ns]	0.95[ns]	0.10[ns]	0.09[ns]
M_{TH}	51–60	0.32 [ns]	0.33[ns]	0.32[ns]	0.33[ns]	0.32[ns]
M_{TR}	51–60	0.49 [ns]	0.97[ns]	0.80[ns]	0.50[ns]	0.54[ns]
T_R	51–60	0.01[**]	0.50[ns]	0.31[ns]	0.07[ns]	0.04[*]
M_{TH}	61–65	0.90 [ns]	0.57[ns]	0.81[ns]	0.97[ns]	0.85[ns]
M_{TR}	61–65	0.48 [ns]	0.10[ns]	0.06[ns]	0.28[ns]	0.28[ns]
T_R	61–65	0.01[**]	0.21[ns]	0.10[ns]	0.04[*]	0.02[*]
M_{TH}	66–70	– 0.05[*]	- 0.01[**]	– 0.00[***]	– 0.02[*]	- 0.01[**]
M_{TR}	66–70	0.93 [ns]	0.58[ns]	0.84 [ns]	0.86[ns]	1.00[ns]
T_R	66–70	0.07 [ns]	0.35[ns]	0.24 [ns]	0.15[ns]	0.11[ns]
M_{TH}	71–75	0.03[*]	0.02[*]	0.59 [ns]	0.08[ns]	0.04[*]
M_{TR}	71–75	0.65 [ns]	0.25[ns]	0.21 [ns]	0.51[ns]	0.73[ns]
T_R	71–75	0.02[*]	0.29[ns]	0.79 [ns]	0.03[*]	0.03[*]
M_{TH}	76–80	– 0.35[ns]	- 0.77[ns]	0.78 [ns]	– 0.45[ns]	- 0.46[ns]
M_{TR}	76–80	0.77[ns]	0.64[ns]	0.11 [ns]	0.43[ns]	0.58[ns]
T_R	76–80	0.79[ns]	0.83[ns]	0.30 [ns]	0.96[ns]	0.96[ns]
M_{TH}	81–85	– 0.0[ns]	- 0.51[ns]	– 0.08[ns]	– 0.26[ns]	- 0.17[ns]
M_{TR}	81–85	– 0.10[ns]	- 0.52[ns]	0.75[ns]	– 0.18[ns]	- 0.21[ns]
T_R	81–85	0.15[ns]	0.16[ns]	0.84[ns]	0.18[ns]	0.14[ns]

[1] Sensory and hedonic terms.
[2] Estimated regression coefficients from ANOVA-Partial Least Squares Regression (APLSR) (ANOVA values). The sign dictates whether the correlation is positively or negatively correlated.
[3] P values: ns = not significant; $*P \leq 0.05$, $**P \leq 0.01$, $***P \leq 0.001$.
[4] Aging treatments: Moderately Tough (M_{TH}) = 2 days, Moderately Tender (M_{TR}) = 7 days and Tender (T_R) = 21 days.

Booth, Conner, and Gibson (1989) suggested that older persons may adjust eating patterns and food preferences to account for diminishing sense of taste and smell. Engelen and Van Der Bilt (2008) found that the physiological process taking part in the buccal cavity, such as salivation (saliva flow, rate and composition) tongue movements and temperate exchanges between food and oral cavity play a vital role in the perception of texture. It was also found that mastication and ability to swallow play a vital role in the perception of food texture. For example, in this study, the 66–70 age assessor category negatively correlated sample T_R for tenderness, whereas the 71–75 age assessor category positively correlated this sample for tenderness. This may be attributed to a diminished perception of texture. Textural recognition by assessors became unclear in the 71–75 age cohort, as panellists failed to identify textural differences in steak samples along treatment lines and accepted tender and tough meat to the same degree. The 71–75 age cohort significantly ($P \leq 0.05$) positively correlated the T_R sample to overall acceptability. This was the only age category to do so. The M_{TH} sample was significantly ($P \leq 0.05$) positively correlated for tenderness and texture. The 76–80 age cohort and the 81–85 age cohort were not able to differentiate the different textures and aging times significantly. In another study, differences between two different age cohorts in relation to the texture and flavour perception of sweet and savoury waffles were examined. It was determined that poor textural sensitivity was not related to perception of sensory attributes (Kremer, Mojet, & Kroeze, 2007). Thus, changing preferences for texture as aging occurs, seems to be dependent on the food product being investigated.

Texture is defined as a dynamic interaction with time between a foods physical proportion and the senses of touch, sight and hearing (Engelen & Van Der Bilt, 2008). It could be hypothesised that this loss of textural acuity in meats may be due to poor dentition (Roininen et al., 2003), sensory decline as the aging process occurs (Morley, 2001), social factors, medications, physical and physiological issues (Donini, Savina, & Cannella, 2003). There are many factors which may be attributed to a changing preference for texture as the human aging process occurs and numerous studies are required to fully understand what these factors are, and how they impact and interact to affect textural perception. Fig. 3.1 displays the age groups over 61 years old dispersed all over the quadrants of the plot, when sample T_R is assessed. The M_{TR} samples can be seen on Fig. 1 on the upper half of the hemisphere, with the exception of the 66–70 age category. The M_{TR} samples are illustrated on the left-hand side of the hemisphere in Fig. 3.1, with the exception of the 76–80 age category. No significant differences were observed for the more senior participants involved in these trials. As can be seen, steak aged from 2 to 21 days is not sufficient for the textural preferences of our the elderly consumers. Consequently, this may result in a decrease in meat consumption by this age cohort. Therefore, the meat industry needs to adopt new practices, or amend current practices, in an attempt to modify meat texture to address the needs of this potentially significant consumer market.

3.4. Conclusions

In summary, this paper provides evidence for a difference in textural preference in various age cohorts. Those aged between 18 and 70 years old successfully identified the attribute differences between the meat sample groups of Moderately Tough (M_{TH}) and Tender (T_R) steak. Samples employed in the study. Attribute blindness was observed in sensory subjects aged from 71 years old. The over 75 age categories (late the elderly) failed to recognise any eating quality difference between steak treatments. Currently, there is very limited information in the literature to support this finding and more research in this area is required, particularly as aging populations present a growing consumer market within which meat could play an important and necessary role. From this research, it could be suggested that the elderly may not purchase beef due to its current tenderisation treatments. It can be concluded that while certain age groups could detect differences in tenderness between steak samples as consumers aged, they became less sensitive to tenderness, and in some cases, unable to detect differences at all. Consequently, it may be necessary to define tenderness values that would be detectable and acceptable to these consumer groupings. Therefore, more research is required in this area so that guidelines could be presented for industrial uptake.

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CHAPTER 4

Sensory optimisation of salt-reduced corned beef for different consumer segments

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Abstract

The study objectives were to determine assessors' (n=256) preference for corned beef, produced with sequential reductions in NaCl concentrations and to determine if preference was affected by assessor age. The use of salt replacers such as potassium lactate and glycine were also assessed. The youngest age cohort disliked samples containing the highest level of NaCl, whereas the oldest age cohort did not detect differences between samples. The most negatively perceived sample was the control, suggesting that NaCl levels added to commercial corned beef are currently too high for consumer acceptance. All age cohorts, except for the 65-74 age cohort, accepted corned beef samples possessing NaCl levels closest to the FSAI target (1.63g/100g). No major sensory differences were noted between samples with and without potassium lactate by the ≥65 age cohort. Potassium lactate may be added to corned beef without affecting sensory attributes, whilst enhancing nutritional content. Assessors of varying age groups have differing preferences for certain NaCl levels and salt replacers.

Keywords

Corned Beef, Potassium Lactate, Salt Reduction Programmes, Age

4.1 Introduction

Salt intake among adults in European Countries ranges from 7-13g per day (Kloss, Meyer, Graeve, & Vetter, 2015). In Ireland, 18-64 year olds have a mean daily intake of 7.4g salt, with men having higher intakes (8.5g) than women (6.2g). Adults aged 65 years and over have a mean daily salt intake of 6.3g, with men having higher intakes (7.3g) than women (5.4g) (IUNA, 2001). Evidence suggests that current levels of sodium consumption in Europe contributes to increased blood pressure in the population and consequently, the prevalence of cardiovascular (CVD) and renal diseases increase (EFSA, 2005). Currently the World Health Organisation (WHO) recommends that adults consume less than 5g of salt per day (WHO, 2010). It was estimated that if the average person would decrease salt intake by about 5g per day, a reduction of 23% of strokes and 17% incidences of CVD would result in preventing an estimated four million deaths annually worldwide (Strazzullo, D'Elia, Kandala, & Cappuccio, 2009). The main source of sodium in the diet is from processed foods (about 70-75% of the total intake) (EFSA, 2005). Salt reduction is a huge challenge for food manufacturers. Not only is taste effected as a consequence of salt reduction, this also impacts processors in their ability to successfully manufacture processed meat products via the extraction of myofibrillar proteins, in addition to achieving preservation requirements in order to maintain product safety and shelf-life (Desmond, 2006). Reductions in salt content in processed foods requires ingredients that do not negatively impact the sensory, safety or stability of the products in question. One salt reduction approach is food reformulation. Since the WHO initiated the Global Strategy on Diet, Physical Activity and Health to limit the levels of *trans* fatty acids, saturated fatty acids, sugar and salt in foods, many companies within the food and beverage sector have reformulated their products (WHO, 2007). The FSA (Food Safety Authority) started a campaign in 2003 to encourage a voluntary reduction of salt in processed foods. A mean salt reduction of 7% between 2006 and 2011 was observed in convenience foods resulting in a lower salt intake in the UK population. Since 2003, the Food Safety Authority of Ireland (FSAI) has coordinated a salt reduction programme working in partnership with the food industry, Food and Drink Industry Ireland (FDII), Retail Ireland, various State bodies and related organisations to achieve voluntary, gradual and sustained reductions in the salt content of processed foods. Through this initiative, they successfully reduced the level of salt in the following processed meat products: rashers by 27%, cooked ham by 15% and sausage products by 11% (FSAI, 2015).

Processed meats are one of the main sources of salt intake in our diets (Desmond, 2006). According to the IUNA (Irish Universities Nutrition Alliance) 47% of 18-64 year olds and 30% of the over 65 age cohort consume processed meat products (IUNA, 2011). This may be due to its high salt content which may appeal to those with declining sensory perception as the aging process occurs (Warwick & Schiffman, 1990). The FSA has recommended a salt reduction to 1.63g (650mg sodium) (Salt-Targets 2017, 2016) and the WHO has recommended a salt reduction level of 1.35g salt (540mg sodium) in corned beef (WHO, 2013). Corned beef was the food matrix chosen for this study. Corned beef is a traditional meat product commonly consumed by the Irish population, particularly senior citizens. According to Cliceri et al. (2017) familiarity with the product is the main factor affecting the consumption among senior citizens.

The use of potassium-based ingredients for salt replacement by the food industry could help supplement intakes of potassium and reduce the intake of sodium by the Irish population (FSAI 2009). However, the FSAI has raised concerns about the health effects of increasing potassium in the diets of sub-groups of the population with Type 1 diabetes, chronic renal insufficiency, end-stage renal disease, severe heart failure and adrenal insufficiency (FSAI, 2015). However, US dietary guidelines states that a high potassium diet helps counteract the effect of salt on blood pressure. They recommended an intake of 4.7g of potassium per day for adults (U.S. Department of Health and Human Services and U.S. Department, 2015). The mean daily potassium intake for Irish adults is 3,784mg/day for men and 2,945mg/day for women (IUNA, 2011). These levels are lower than current U.S. recommendations for potassium of 4,700mg/day for women (U.S. Department of Health and Human Services and U.S. Department, 2015), but higher for men than WHO recommendations of 3,510mg/day (WHO, 2012). Many salt reducing studies replace NaCl with potassium chloride. However, Potassium chloride (KCl) has been found to exert a metallic and bitter taste when used in foods as a NaCl replacement (Dötsch et al., 2009).

Potassium lactate is used as a salt replacer for low sodium foods as it possesses salt-like functionality, has strong water binding properties and is antimicrobial Shelef. (1994). However, potassium lactate has no off-flavours that are often associated with potassium-based products. Potassium lactate has been shown to be an effective salt replacer in meat products (Guàrdia, Guerrero, Gelabert, Gou, & Arnau (2008), Fulladosa, Serra, Gou, & Arnau (2009) & Choi, Jung, Jo, H. M., Nam, Choe, Rhee, & Kim (2014)). Combined effects of potassium lactate and calcium ascorbate as sodium chloride substitutes on the physicochemical and sensory characteristics of low-sodium frankfurter sausage. Sensory characterisation and consumer acceptability of small calibre fermented sausages with 50% substitution of NaCl by mixtures of KCl and potassium lactate. Effects of potassium lactate and high pressure on transglutaminase restructured dry-cured hams with reduced salt content, due to its antimicrobial properties (Terrell, 1983). Therefore, the objective of this study was to determine assessors’ preferences for sequential reductions in salt concentrations in optimised corned beef products and to determine if preference was affected by assessor age.

4.2 Materials and Methods

4.2.1 Reagents and chemicals

Sulphuric acid, hydrogen peroxide, boric acid, hydrochloric acid, sodium hydroxide, silver nitrate and potassium lactate were supplied by Sigma-Aldrich Ireland Ltd., Vale Road, Arklow, Wicklow, Ireland.

4.2.2 Sample Preparation

Beef (M. Semitendinous) samples were obtained from a local supplier (Ballyburden, Cork, Ireland). Beef was sourced from the local supplier on three separate occasions. Visible fat was trimmed from the beef and the samples were portioned to obtain a standard weight of 2.0kg. According to Fellendorf et al. 2018 (in press) a reduction of 60% salt in corned beef was accepted by assessors ($P \leq 0.05$) for flavour in sodium-reduced corned beef via the incorporation of 0.4% sodium and formulated with potassium lactate and glycine. Consequently, this formulation was included in this product process design.

To determine the effects of salt reduction on corned beef, a commercial reference level similar to corned beef sold at a retail level was established. A salt content of 2.0% was decided upon as the control sample (C). A higher level of 2.4% NaCl was utilised to gauge consumer's preference on higher salt addition. A moderately reduced salt level (1.5g, 20-25% reduction) was chosen and implemented to be in line with FSA guidelines (Food Standards Agency, 2009). A greatly reduced salt level was chosen and implemented so that levels (1.0g NaCl and 0.6g potassium lactate; 1.0g NaCl) were lower than set by the WHO guidelines (WHO, 2010). All formulations employed were based around proximate analysis of salt content. All experimental formulations for corned beef samples are shown in Table 4.1. The lowest level of NaCl was added at level of 0.5%. Salt replacers were also added to one formulation and included potassium lactate and Glycine (Table 4.1). Six treatment batches were manufactured on three separate occasions (n=3). All samples were analysed for proximate compositional analysis, sensory analysis, and physical analysis. The curing solution was mixed for 3min at 3500rpm using a Silverson Axr mixer (Dartmouth, USA). A single needle (4mm diameter needle) hand injector was used (Friedr Dick GmbH & Co. KG, Deizisau, Germany) to inject the homogenised curing solution into the beef muscles until a 20% increase in weight was achieved. These samples were then placed in an OPA/PP laminate bag and vacuum packed (Fispak, Dublin, Ireland). All samples were the stored in the chill at 4°C for 24hr.

4.2.3 Cooking

The injected samples were cooked in a Zanussi convection oven (C. Batassi, Conegliano, Italy) with 100% steam at 85°C for 3hr. The product was cooked to an internal temperature of 73 °C. Cooking temperature was monitored using a temperature probe (Testo 110, Lenkirch, Germany). After cooking, all samples were transferred to the chill at 4°C.

Table 4.1: Formulation table of curing solution

Sample	**NaCl(g)/1L curing solution [***]**	**KNO_2/1L curing solution (g/1L)**	**K (lactate(g))/1L curing solution**	**Glycine(g)/1L curing solution**
1.0 NaCl & 0.6Kl [*]	60.96	0.11	20.32	20.32
C[**]	152.4	0.11	0.00	0.00
2.0 NaCl	121.92	0.11	0.00	0.00
1.5 NaCl	91.44	0.11	0.00	0.00
1.0 NaCl	60.96	0.11	0.00	0.00
0.5 NaCl	30.48	0.11	0.00	0.00

[*] 1.0 NaCl & 0.6 Kl (expressed as %) = Sample containing salt replacers; Kl & Glycine

[**] C = Control sample

[***] All samples expressed in grams per 1L of curing solution

Kl = Potassium Lactate

4.3 Proximate Compositional Analysis

4.3.1 Protein Content

Protein was determined using the Kjeldahl method with slight modifications (Suhre FB , Corrao PA , Glover A, 1982). The digestion block was pre-heated (410°C). A well homogenised sample (0.8g) was weighed and placed in a digestion tube.

The tubes were placed in the heated digestion block. Samples were then removed from the digestion block and tubes cooled in the fume hood. Distilled water (50ml) was added to the cooled sample and the tubes were placed into the distillation unit along with 4% boric acid (50ml) with indicator. When distillation was completed the boric acid with indicator were titrated against 0.1N hydrochloric acid until the green colour reverted to the red colour. Percentage protein was calculated using a nitrogen conversion factor of 6.25. This method was in accordance with the work outlined by Tobin, O'Sullivan, Hamill, & Kerry (2013). The results recorded represented the average of six measurements (three independent batches x two samples x one reading).

4.3.2 Ash Content

Ash content of the corned beef was measured using a muffle furnace (Nabertherm GmbH, Lilienthal, Germany). The muffle furnace was preheated to 525°C. A 5g blended sample was weighted into a porcelain dish and placed in the muffle furnace for 6 hr., until the colour of the samples turned white. The samples were placed in a desiccator to cool. The dishes were weighted, and the ash content was calculated. The results recorded represent the average of six measurements (three independent batches x two samples x one reading).

4.3.3 Moisture and Fat

A total of 1.0g for each corned beef sample was homogenised. Samples were then analysed using the SMART Trac System (CEM GmnH, Kamp- Lintfort, Germany) for analysing moisture and fat (Bostian ML , Fish DL , Webb NB, 1985). Results recorded represented the average of six measurements (three independent batches x two samples x one reading).

4.3.4 Salt

Salt concentrations were measured in accordance with the methods of Fox (1963) using the potentiometric method for salt determination. Corned beef samples were homogenised thoroughly. A 2g sample was added to 100ml of dilute nitric acid solution (1.5ml conc. Nitric acid/L). The samples were then placed in a water bath at 60°C for 15min. Samples were then titrated with 0.1M $AgNO_3$ to +255mV using a potentiometer equipped with silver and reference electrodes. During titration, a magnetic stirrer was used. A blank titration was also carried out. By means of the ratio to chloride, sodium chloride concentrations were calculated in samples. The results recorded represent the average of six measurements (three independent batches x two samples x one reading).

4.3.5 Potassium lactate

Sodium lactate and sodium diacetate were analysed by blending 5g of the homogenised sample with 30ml of distilled water using a polytron for 30sec. The mixture was subsequently centrifuged (20min at 600g) and altered through Whatman no.1 filter paper into a clean 50ml disposable centrifuge tube. The sample was extracted using an ultrasonic bath. An aliquot of filtrate was subsequently filtered a second time with a 0.2μ m membrane filter and transferred to an auto injector vial. Organic acids content was determined by a HPLC (high performance liquid chromatography) method with UV (ultra violet) detection. Filtrates were analysed directly by using a high-performance liquid chromatograph (Perkin Elmer Series 200) with a flow rate of 0.6ml/min, an injection of 20μl, a 220nm detector, and a run time of 20 to 30 min (Seman, Borger, Meyer, Hall, & Milkowski, 2002). Results recorded represent the average of six measurements (three independent batches x two samples x one reading).

4.3.6 Carbohydrates

Total carbohydrates were determined by difference: A 100g sample quantity minus the addition of protein, fat, water and ash in grams, expressed as a percentage. The results recorded represent the average of six measurements (three independent batches x two samples x one reading).

Table 4.2: Hedonic and intensity sensory attributes

Attribute	Definition	Scale
Hedonic		
Appearance	Liking of appearance	0 = extremely dislike 10= extremely like
Flavour	Liking of flavour	0 = extremely dislike 10= extremely like
Texture	Liking of texture	0 = extremely dislike 10= extremely like
Colour	Liking of colour	0 = extremely dislike 10= extremely like
Acceptability	Acceptability of sample	0 = extremely dislike 10= extremely like
Intensity		
Beef Flavour	Taste sensation typically associated with beef	0=none 10=extreme
Saltiness	Taste sensation of which salt is typical	0=none 10=extreme
Beef Aroma	Orthonasal sensation typically associated with beef	0=none 10=extreme
Off-flavour	Off-flavour (rancid) flavour not typically associated with corned beef	0=none 10=extreme
Metallic Flavour	A taste remaining in the mouth of coins/metal after eating	0=none 10=extreme

4.4 Sensory Analysis

4.4.1 Recruitment

Panellists of varying age cohorts were recruited for this study. Panellists were chosen in compliance with the following criteria; community dwelling, health status, potential allergies, swallowing difficulties, and regular consumers of corned beef. Trial subjects were recruited from University College Cork and from active retirement groups based around the Cork region to allow for an older consuming demographic within the study. Assessor cohorts were derived from various socio-economic backgrounds and were gender balanced. Sensory analysis was carried out on untrained assessors (n=256). The ages ranged from 18-85 years of age. The sample size of the various age cohorts was as follows; 18-24 (n=33), 25-34 (n=43), 35-44 (n=40), 45-54 (n=51), 65-74 (n=45) & 75+ (n=44). In accordance with the health concerns issued by the FSAI, panellists were required to fill out a disclaimer indicating that they did not have any of the following aliments: Type 1 diabetes, chronic renal insufficiency, end stage renal disease, severe heart failure and adrenal insufficiency (FSAI, 2015).

4.4.2 Sensory Evaluation

Each panellist rated the sensory qualities of the samples in triplicate on triplicate batches (each batch manufactured separately), according to the methods of the American Meat Science Association (AMSA, 2015). All samples were served cold and they were cut into 3mm thick slices. All samples were presented to assessors on a white polystyrene plate. Each sample was presented at random with corresponding codes on the plate. Panellists were asked to rinse their mouths with water in between each sample in accordance with the methods of Tobin et al

(2012). The experiment was conducted in panel booths which conformed to international standards (ISO, 2007). Panellists were asked to rate the coded and order randomised samples using an ten-point continuous line scale (AMSA, 2015). The following hedonic attributes were assessed; appearance, flavour, texture, colour and overall acceptability. The following intensity attributes were examined; beef aroma, saltiness, beef flavour and off-flavour. The definitions presented to each panellist are outlined in Table 4.2.

Table 4.3: Significance of relationships between sensory descriptors, fixed (treatment, age and treatment*age interaction) and random factors (session, batch and panellist)

	Hedonic					Intensity				
Sensory	**Appearance**	**Flavour**	**Texture**	**Colour**	**Acceptability**	**Beef aroma**	**Saltiness**	**Beef flavour**	**Off-flavour**	**Metallic flavour**
Treatment	0.922^{ns}	0.446	0.961^{ns}	0.974^{ns}	0.908^{ns}	0.465^{ns}	0.865^{ns}	0.764^{ns}	0.935^{ns}	0.367^{ns}
Age	0.513^{ns}	0.000***	0.316^{ns}	0.704^{ns}	0.000***	0.974^{ns}	0.049*	0.178^{ns}	0.017*	0.000***
Age * Treatment	0.901^{ns}	0.903^{ns}	0.879^{ns}	0.898^{ns}	0.982^{ns}	0.948^{ns}	0.009**	0.857^{ns}	0.613^{ns}	0.048*
Session	0.092^{ns}	0.007**	0.029*	0.022*	0.051*	0.017*	0.000***	0.140^{ns}	0.139^{ns}	0.379^{ns}
Batch	0.092^{ns}	0.007**	0.029*	0.022*	0.051*	0.017*	0.000***	0.140^{ns}	0.139^{ns}	0.379^{ns}
Panellist	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***

P values of regression coefficients; * = ($P \leq 0.05$), ** = ($P \leq 0.01$), *** = ($P \leq 0.001$) ^{ns} = non-significant

Kl = Potassium Lactate

4.5 Physical Analysis

4.5.1 Texture Profile Analysis

After cooking, corned beef samples were cooled to room temperature (20°C) to determine textural properties using a texture profile analyser; Texture Analyser 16 TA-XT2I (Stable Micro Systems, Surrey, UK) following AMSA (2015) guidelines. Core samples were taken (12mm diameter) parallel to muscle fibre orientation and then cut with a test speed of 3.0mm/s using a Warner–Bratzler blade. A 25kg load cell was used throughout testing. Textural factors were measured using descriptors highlighted by Bourne (1978). They included hardness (N): maximum force required for the initial sample compression, springiness (mm): the samples' ability to recover its original shape after initial compression and following the deforming force having been removed, cohesiveness (dimensionless): extent to which the sample could be deformed prior to rupture, measured by the areas under the compression portion instead of using the total area under positive force and resilience (dimensionless): the ratio between the negative force input to positive force input during the first compression. The results recorded represent the average of six measurements (three independent batches x two samples x one reading).

4.5.2 Colour

Colour was measured on cooked corned beef sliced samples. Samples were analysed at room temperature (20°C). Colour analysis was carried out using a Minolta CR400 Colour Meter (Minolta Camera Co. Osaka Japan). Lightness (L), redness (a ± red-green) and yellowness (b ± yellow-blue) were measured. The colourmeter features an 11mm – diameter aperture and D65 illuminant, calibrated by the CIE Lab colour space system using a white tile (C: y = 93.6, x = 0.3130, y = 0.3193). A CIE 19312 degrees standard observer was used. A minolta calibration plate was used to calibrate the analysis. Colour was measured by following AMSA guidelines (AMSA, 2012). Duplicate colour measurements were recorded on two samples from each experimental batch.

4.5.3 Cooking Loss

Prior to cooking, all samples were taken out of the OPA/PP vacuum bags and weighed. After cooking the weight of the samples were recorded again. The differences in weights were recorded. Before weighing, each sample was blotted with a paper towel to remove excess moisture. Cooking loss was determined as the difference between cooked and raw weights expressed as a percentage of the raw weight. The results recorded represent the average of six measurements (three independent batches x two samples x one reading).

4.6 Statistical Analysis

A mixed model ANOVA was conducted in SPSS. The following interactions were measured: Treatment, age, age*treatment, session, batch and panellist. The fixed effects included treatments and panellist's ages. The batches, panellists and sessions were included as random effects. Tukeys HSD post hoc test was used to determine significant differences within the groups. The results can be viewed in Table 4.3. Data obtained from the corned beef sensory trials were analysed using ANOVA – Partial Least Squares Regression (APLSR) to process the mean data accumulated from the test subjects. Data was processed using Unscrambler software version 10.3. (CAMO ASA, Trondheim, Norway). The X-matrix was designed as different age categories and the corned beef samples. The Y – matrix involved the intensity and hedonic attributes of the design. The fixed effects were age cohorts and the random effects were sensory results and corned beef samples. Principal components i.e. PC 1 versus PC 2 are presented (Fig. 1). Regression coefficients were analysed by Jack-knifing for intensity and hedonic attributes (Tables 4.4 & 4.5) to derive significant indicators for the relationships determined in the quantitative APLSR, which is based on cross validation and stability plots.

Proximate (Table 4.6) and physiochemical (Table 4.7) compositional analysis data are presented as the mean values±standard error of the mean (SEM). One-way ANOVA was used to examine the data from proximate and physiochemical analysis. The data was subjected to descriptive analysis and tests for normality (Shapiro-Wilk test), Independence and Equality of Variances (Levene's test) were performed. The assumptions of the relevant statistical tests were satisfied in all cases. Tukey's post-hoc test was used to adjust for multiple comparisons between treatment means. All statistical analysis was carried out using the SPSS 11.0 software package for Windows (SPSS, Chicago, IL, USA).

Table 4.4: ANOVA-Partial Least Squares regression illustrating the samples and age cohort's vs the hedonic sensory attributes

Sample	Age Cohort	Appearance	Flavour	Texture	Colour	Acceptability
[1] 1 NaCl & 0.6 Kl	(18-24)	[2]-0.362 [3] ^{ns}[4]	-0.436 ^{ns}	-0.444 ^{ns}	-0.584 ^{ns}	-0.655 ^{ns}
	(25-34)	-0.439 ^{ns}	-0.326 ^{ns}	-0.332 ^{ns}	-0.447 ^{ns}	-0.335 ^{ns}
	(35-44)	0.000 ***	0.000 ***	0.032 *	0.079 ^{ns}	0.088 ^{ns}
	(45-64)	0.120 ^{ns}	0.100 ^{ns}	0.225 ^{ns}	0.298 ^{ns}	0.342 ^{ns}
	(65-74)	-0.101 ^{ns}	-0.127 ^{ns}	-0.265 ^{ns}	-0.346 ^{ns}	-0.345 ^{ns}
	(75+)	0.186 ^{ns}	0.215 ^{ns}	0.321 ^{ns}	0.387 ^{ns}	0.401 ^{ns}
2.0 NaCl	(18-24)	-0.032 *	-0.000 ***	-0.005 **	-0.007 **	-0.000 ***
	(25-34)	0.648 ^{ns}	0.321 ^{ns}	0.624 ^{ns}	0.699 ^{ns}	0.465 ^{ns}
	(35-44)	0.007 **	0.007 **	0.092 ^{ns}	0.156 ^{ns}	0.178 ^{ns}
	(45-64)	0.080 ^{ns}	0.104 ^{ns}	0.232 ^{ns}	0.290 ^{ns}	0.325 ^{ns}
	(65-74)	-0.588 ^{ns}	-0.680 ^{ns}	-0.607 ^{ns}	-0.621 ^{ns}	-0.659 ^{ns}
	(75+)	0.101 ^{ns}	0.085 ^{ns}	0.226 ^{ns}	0.300 ^{ns}	0.329 ^{ns}
C	(18-24)	-0.000 ***	-0.000 ***	-0.080 ^{ns}	-0.039 *	-0.003 **
	(25-34)	-0.000***	-0.000 ***	-0.001***	-0.011 **	-0.000 ***
	(35-44)	0.002 **	0.009 **	0.157 ^{ns}	0.264 ^{ns}	0.213 ^{ns}
	(45-64)	0.086 ^{ns}	0.138 ^{ns}	0.307 ^{ns}	0.401 ^{ns}	0.381 ^{ns}
	(65-74)	-0.325 ^{ns}	-0.233 ^{ns}	-0.405 ^{ns}	-0.386 ^{ns}	-0.291 ^{ns}
	(75+)	-0.131 ^{ns}	-0.049 *	-0.138 ^{ns}	-0.114 ^{ns}	-0.089 ^{ns}
1.5 NaCl	(18-24)	0.823 ^{ns}	0.626 ^{ns}	0.623 ^{ns}	0.688 ^{ns}	0.233 ^{ns}
	(25-34)	0.606 ^{ns}	0.801 ^{ns}	0.716 ^{ns}	0.779 ^{ns}	0.849 ^{ns}
	(35-44)	0.005**	0.008 **	0.118 ^{ns}	0.190 ^{ns}	0.191 ^{ns}
	(45-64)	0.127 ^{ns}	0.073 ^{ns}	0.162 ^{ns}	0.240 ^{ns}	0.307 ^{ns}
	(65-74)	-0.011**	-0.025 *	-0.189 ^{ns}	-0.283 ^{ns}	-0.290 ^{ns}
	(75+)	0.206 ^{ns}	0.289 ^{ns}	0.383 ^{ns}	0.457 ^{ns}	0.500 ^{ns}
1.0 NaCl	(18-24)	0.332 ^{ns}	0.024 *	0.155 ^{ns}	0.026 *	0.007 **
	(25-34)	0.021*	0.040 *	0.162 ^{ns}	0.236 ^{ns}	0.232 ^{ns}
	(35-44)	0.015**	0.005 **	0.078 ^{ns}	0.131 ^{ns}	0.150 ^{ns}
	(45-64)	0.063 ^{ns}	0.021*	0.101 ^{ns}	0.158 ^{ns}	0.194 ^{ns}
	(65-74)	-0.682 ^{ns}	-0.648 ^{ns}	-0.673 ^{ns}	-0.647 ^{ns}	-0.612 ^{ns}
	(75+)	0.250 ^{ns}	0.280 ^{ns}	0.375 ^{ns}	0.437 ^{ns}	0.479 ^{ns}
0.5 NaCl	(18-24)	0.668 ^{ns}	0.064 ^{ns}	0.850 ^{ns}	0.682 ^{ns}	0.334 ^{ns}
	(25-34)	0.726 ^{ns}	0.367 ^{ns}	0.651 ^{ns}	0.590 ^{ns}	0.268 ^{ns}
	(35-44)	0.029*	0.002 **	0.053*	0.094 ^{ns}	0.119 ^{ns}
	(45-64)	0.092 ^{ns}	0.025 ^{ns}	0.103 ^{ns}	0.162 ^{ns}	0.210 ^{ns}
	(65-74)	-0.647 ^{ns}	-0.532 ^{ns}	-0.686 ^{ns}	-0.586 ^{ns}	-0.503 ^{ns}
	(75+)	-0.804 ^{ns}	-0.997 ^{ns}	-0.824 ^{ns}	-0.893 ^{ns}	-0.972 ^{ns}

[1] Sample and age group, [2] the sign dictates whether the correlation is positively or negatively correlated, [3] estimated regression coefficients from ANOVA-Partial Least Squares Regression (APLSR) (ANOVA values), [4] *P* values: ns= not significant; $^{*}P \leq 0.05$, $^{**}P \leq 0.01$, $^{***}P \leq 0.001$. Kl = Potassium Lactate

Table 4.5: ANOVA-Partial Least Squares regression illustrating the samples and age cohort's vs the intensity sensory attributes

Sample	Age Cohort	Beef Aroma	Saltiness	Beef Flavour	Off Flavour	Metallic Flavour
[1] 1 NaCl & 0.6 Kl	(18-24)	-[2] 0.321[3] ns[4]	-0.322 ns	-0.359 ns	-0.683 ns	-0.669 ns
	(25-34)	-0.929 ns	-0.879 ns	-0.653 ns	0.574 ns	0.653 *
	(35-44)	0.077 ns	-0.516 ns	0.012 **	-0.002 **	0.007 **
	(45-64)	0.207 ns	-0.677 ns	0.168 ns	-0.130 ns	0.164 *
	(65-74)	-0.372 ns	0.652 ns	-0.143 ns	0.218 ns	-0.085 *
	(75+)	0.373 ns	-0.653 ns	0.209 ns	-0.266 ns	-0.187 *
2.0 NaCl	(18-24)	-0.205 ns	0.395 ns	-0.006 **	0.289 ns	0.559 ns
	(25-34)	0.570 ns	-0.545 ns	0.528 ns	-0.652 ns	-0.838 ns
	(35-44)	0.121 ns	-0.589 ns	0.023 *	-0.026 *	-0.025 *
	(45-64)	0.250 ns	-0.670 ns	0.136 ns	-0.150 ns	-0.125 ns
	(65-74)	-0.497 ns	0.987 ns	-0.341 ns	0.745 ns	0.725 ns
	(75+)	0.262 ns	-0.641 ns	0.196 ns	-0.113 ns	-0.120 ns
C	(18-24)	-0.072 ns	0.003 **	-0.000 ***	0.063 ns	0.067 ns
	(25-34)	-0.579 ns	0.136 ns	-0.062 ns	0.003 **	0.093 ns
	(35-44)	0.412 ns	-0.530 ns	0.014 **	-0.170 ns	-0.003 **
	(45-64)	0.472 ns	-0.639 ns	0.127 ns	-0.306 ns	-0.098 ns
	(65-74)	-0.506 ns	0.187 ns	-0.307 ns	0.434 ns	0.467 ns
	(75+)	-0.166 ns	0.312 ns	-0.181 ns	0.094 ns	0.248 ns
1.5 NaCl	(18-24)	0.967 ns	-0.881 ns	0.669 ns	-0.947 ns	-0.936 ns
	(25-34)	0.704 ns	-0.927 ns	0.426 ns	-0.789 ns	-0.663 ns
	(35-44)	0.220 ns	-0.559 ns	0.030 *	-0.041 *	-0.006 **
	(45-64)	0.126 ns	-0.735 ns	0.169 ns	-0.081 ns	-0.215 ns
	(65-74)	-0.298 ns	0.628 ns	-0.047 *	0.113 ns	0.007 **
	(75+)	0.382 ns	-0.738 ns	0.197 ns	-0.323 ns	-0.193 ns
1.0 NaCl	(18-24)	0.371 ns	-0.439 ns	0.123 ns	-0.568 ns	-0.959 ns
	(25-34)	0.244 ns	-0.546 ns	0.042 *	-0.122 ns	-0.043 *
	(35-44)	0.105 ns	-0.567 ns	0.060 ns	-0.010 **	-0.043 *
	(45-64)	0.100 ns	-0.633 ns	0.127 ns	-0.026 *	-0.133 ns
	(65-74)	-0.664 ns	0.802 ns	-0.537 ns	0.773 ns	0.830 ns
	(75+)	0.375 ns	-0.703 ns	0.328 ns	-0.269 ns	-0.223 ns
0.5 NaCl	(18-24)	0.993 ns	-0.337 ns	0.682 ns	-0.916 ns	-0.476 ns
	(25-34)	0.869 ns	-0.521 ns	0.848 ns	-0.722 ns	-0.856 ns
	(35-44)	0.052*	-0.562 ns	0.099 ns	-0.003 **	-0.094 ns
	(45-64)	0.083 ns	-0.648 ns	0.174 ns	-0.027 *	-0.187 ns
	(65-74)	-0.577 ns	0.366 ns	-0.491 ns	0.689 ns	0.799 ns
	(75+)	-0.705 ns	0.931 ns	-0.823 ns	0.761 ns	0.636 ns

[1] Sample and age group, [2] the sign dictates whether the correlation is positively or negatively correlated, [3] estimated regression coefficients from ANOVA-Partial Least Squares Regression (APLSR) (ANOVA values), [4] *P* values: ns= not significant; $^{*}P \leq 0.05$, $^{**}P \leq 0.01$, $^{***}P \leq 0.001$. Kl = Potassium Lactate

Table 4.6: Proximal Compositional Analysis Values for Corned Beef

Sample	Fat (%)	Ash (%)	Moisture (%)	Protein (%)	Carbohydrates (%)	NaCl (%)	Kl (%)
1 NaCl & 0.6 Kl*	3.6 ± 0.00[a]	1.9 ± 0.03[d]	63.5 ± 0.18[ab]	29.0 ± 0.01[a]	1.6 ± 0.18[a]	1.0 ± 0.00[b]	0.6 ± 0.00[a]
C**	4.4 ± 0.01[b]	0.9 ± 0.00 [a]	59.9 ± 0.99 [a]	29.7 ± 0.13[b]	3.1 ± 0.99[a]	2.4 ± 0.05[e]	0.0 ± 0.00[b]
2.0 NaCl	4.1 ± 0.02[c]	2.8 ± 0.00[f]	60.3 ± 0.49[a]	30.0 ± 0.01[a]	2.9 ± 0.49[a]	2.0 ± 0.00[d]	0.0 ± 0.00[b]
1.5 NaCl	2.9 ± 0.03[d]	2.2 ± 0.02[e]	61.9 ± 1.57[ab]	30.1 ± 0.06[a]	3.6 ± 1.57[a]	1.5 ± 0.00[c]	0.0 ± 0.00[b]
1.0 NaCl	2.5 ± 0.01[e]	1.7 ± 0.00[c]	62.3 ± 0.18[ab]	31.1 ± 0.01[a]	0.7 ± 0.18[a]	1.0 ± 0.00[b]	0.0 ± 0.00[b]
0.5 NaCl	3.0± 0.00[f]	1.1 ± 0.01[b]	64.15 ± 0.31[b]	29.8 ± 0.01[a]	0.6 ± 0.31[a]	0.5 ± 0.00[a]	0.0 ± 0.00[b]

[abcdef] Mean values (± standard error of the mean) in the same column bearing different superscripts are significantly different, $P \leq 0.05$

* 1.0 NaCl & 0.6 Kl (expressed as %) = Sample containing salt replacers; Kl & Glycine (Kl = Potassium Lactate)

** C = Control sample

Table 4.7: Physiochemical compositional analysis values for corned beef

Sample	l	a	B	Hardness (N)	Springiness (mm)	Cohesiveness (na) ♦	Resilience (na) ♦	Cooking Loss (%)
1 NaCl & 0.6 Kl*	60.6 ± 0.01^{a}	16.3 ± 0.00^{c}	10.1 ± 0.00^{a}	24.6 ± 0.01^{bc}	0.8 ± 0.01^{b}	0.5 ± 0.01^{bc}	0.2 ± 0.00^{b}	37.2 ± 0.01^{a}
2.0 NaCl	63.2 ± 0.00^{b}	16.3 ± 0.06^{b}	9.9 ± 0.01^{b}	22.8 ± 0.01^{a}	0.8 ± 0.01^{b}	0.5 ± 0.01^{c}	0.2 ± 0.00^{bc}	38.3 ± 0.00^{b}
C**	58.5 ± 0.00^{c}	16.9 ± 0.01^{b}	13.2 ± 0.00^{c}	26.5 ± 0.00^{abc}	0.7 ± 0.00^{ab}	0.5 ± 0.01^{bc}	0.2 ± 0.00^{bc}	40.4 ± 0.01^{e}
1.5 NaCl	58.4 ± 0.00^{d}	18.3 ± 0.00^{c}	12.4 ± 0.00^{d}	24.3 ± 0.00^{ab}	0.7 ± 0.02^{ab}	0.4 ± 0.00^{a}	0.2 ± 0.00^{a}	39.9 ± 0.01^{c}
1.0 NaCl	57.2 ± 0.01^{e}	17.9 ± 0.00^{a}	11.9 ± 0.00^{e}	24.2 ± 0.00^{a}	0.7 ± 0.00^{a}	0.4 ± 0.00^{ab}	0.2 ± 0.00^{b}	40.3 ± 0.00^{d}
0.5 NaCl	56.7 ± 0.00^{f}	17.7 ± 0.01^{c}	10.8 ± 0.00^{f}	24.3 ± 0.01^{c}	0.8 ± 0.09^{b}	0.5 ± 0.01^{bc}	0.2 ± 0.00^{c}	40.4 ± 0.02^{e}

^{abc} Mean values (± standard error of the mean) in the same column bearing different superscripts are significantly different, $P \leq 0.05$

♦ (n/a) Cohesiveness & resilience measurement is dimensionless

* 1.0 NaCl & 0.6 Kl (expressed as %) = Sample containing salt replacers; Kl & Glycine

** C = Control sample

Kl = Potassium Lactate.

4.7 Results & Discussion

4.7.1 Sensory Analysis

From Table 4.2 panelist's interaction significantly affected all of the hedonic and the intensity sensory descriptors. Results from the sensory evaluation of corned beef with varying salt levels and replacers are displayed in APLSR plot (Fig. 4.1) and the corresponding ANOVA values (*P* values of beta-coefficients), including significance and correlation factors presented in Table 4.4 for hedonic and Table 4.5 for intensity sensory assessments. The attributes of 'saltiness', 'off flavour' and 'metallic flavour' are located on the top right-hand side of the plot (Fig. 4.1). Liking of texture, acceptability, appearance, colour and flavour were all located on the bottom left quadrant. Many studies have demonstrated that flavour and texture are the key sensory factors driving assessors preference for beef products (Morgan et al., 1991; Lorenzen, Neely, Miller & Tatum, 1999; Boleman et al., 1997).

The 35-44 age cohort liked corned beef samples which contained 1.0% NaCl & 0.6% Potassium lactate for the following attributes: appearance, flavour and texture ($P \leq 0.001$), ($P \leq 0.001$) and ($P \leq 0.05$), respectively (Table 4.4). This age group associated this sample with beef flavour ($P \leq 0.01$) and metallic flavour (Table 4.5). This age cohort was the only age cohort to like the 1.0% NaCl and 0.6% potassium lactate corned beef sample. Salt reduction may impact consumer subgroups differently. In a salt replacement trial conducted by Guàrdia, Guerrero, Gelabert, Gou, & Arnau, (2008), it was concluded that a reduction of 50% NaCl in fermented sausages could be carried out successfully by substitution with 50% KCl or with a mixture of KCl/K-lactate (40:10) without changing the overall acceptability of the product, independently of gender, residence, educational level or assessor age. However, cluster results showed that there could be some groups of assessors who would accept other mixtures of KCl/K-lactate as salt substitutes (20:30 and 30:20) (Guàrdia et al., 2008). From Fig 1. the majority of corned beef samples containing potassium lactate were associated with attributes such as beef aroma, beef flavour, appearance, liking of colour, liking of flavour, acceptability and liking of texture. This finding is in accordance with the work of Fellendorf et al. (2017) (in press) who found that corned beef with a mixture of NaCl (0.40%) and Potassium lactate (0.02%) was accepted for its flavour in a consumer trial. Gelabert, Gou, Guerrero, & Arnau, (2003) conducted a salt reduction trial on fermented sausages. NaCl was reduced by the addition of potassium lactate and glycine. At levels above 40%, the combination of both salt replacers negatively impacted upon the texture and flavour qualities of the product. In contrast, Fulladosa, Serra, Gou, & Arnau, (2009) found that potassium lactate did not negatively impact upon the flavour or texture of cured hams.

Corned beef samples containing 2.4% salt represented products containing the highest amount of NaCl (Table 4.6) of all the samples investigated. The 18-24 age group did not like this high salt sample for its appearance, flavour, texture, colour and acceptability ($P \leq 0.05$), ($P \leq 0.001$), ($P \leq 0.01$), ($P \leq 0.01$) and ($P \leq 0.001$), respectively (Table 4.4). This was an unexpected result as younger age groups have been found to prefer saltier foods (Wansink, Cheney, & Chan 2003). Exploring comfort food preferences across age and gender. Physiology & behavior, 79(4-5), 739-747. The sensory acuity of this group was very accurate as they perceived the high NaCl sample negatively. The 18-24 age group also did not perceive beef flavour in this sample ($P \leq 0.01$). The 35-44 age group liked samples containing 2.4% NaCl for appearance and flavour ($P \leq 0.01$) (Table 4.4). NaCl is a flavour enhancer due to of its effect on different biochemical mechanisms (Albarracín, Sánchez, Grau, & Barat, 2011). The 35-44 age group did not associate the sample containing 2.4% NaCl with off-flavour or metallic flavour ($P \leq 0.05$) (Table 4.5). The older age cohorts did not perceive the high NaCl (2.4%) samples as positive. Taste detection and taste recognition for the five basic tastes (sweet, sour, bitter, umami & salty) and have been proven to decline as the aging process occurs (Schiffman, 1993;

Schiffman, 1998; Warwick & Schiffman, 1990 & Mojet, 2003). An increased detection threshold may indicate that the elderly require the presence of more molecules for a sensation to be perceived compared to younger subjects. An increased recognition threshold indicates that a higher concentration of the tastant is needed before it can be identified correctly (Schiffman, 2008).

The control sample contained 2.0% NaCl in the final product, which is double that in samples containing 1% NaCl & 0.6% potassium lactate and the sample containing 1.0% NaCl. This sample was used as the control sample as it has the closest NaCl value to commercial corned beef samples. The 18-24 age group associated the control sample with saltiness ($P \leq 0.01$) (Table 4.5). This age cohort did not perceive a beef flavour with the sample possibly due to the high salt concentration. This age cohort could also identify the higher salt content sample. Many studies have demonstrated the superior sensitivity ability of younger assessors to identify flavours over older age cohorts (Schiffman, 1977; Philipsen, Clydesdale, Griffin, & Stern, 1995). Research has demonstrated that thresholds for many tastes and odours can be as much as twelve-times higher in the senior citizens compared to younger subjects (Schiffman & Warwick, 1989). The 25-34 age group did not like the control sample for appearance, flavour, texture, colour and acceptability ($P \leq 0.001$), ($P \leq 0.001$), ($P \leq 0.001$), ($P \leq 0.01$) and ($P \leq 0.001$), respectively (Table 4.4), whereas, the 35-44 age cohort liked the control sample for appearance, flavour and beef flavour and they did not perceive a metallic taste with the control sample (Table 4.5). The 75+ age group did not like the control sample for flavour ($P \leq 0.05$) (Table 4.4) and also disliked the high salt content. Similar findings have been found whereby older subjects preferred less salty soups than young adults (Drewnowski, Henderson, Driscoll, & Rolls, 1996). This evidence conflicts with the theory that older assessors have a preference for saltier foods. Little or no effect of age was found when the perceived saltiness of mashed potatoes was measured (Zallen, Hooks, & O'Brien, 1990).

An overview of the loadings of the X and Y variables for the first two PCs for the individual treatments and age categories ● V's hedonic ■ and intensity attributes ◆

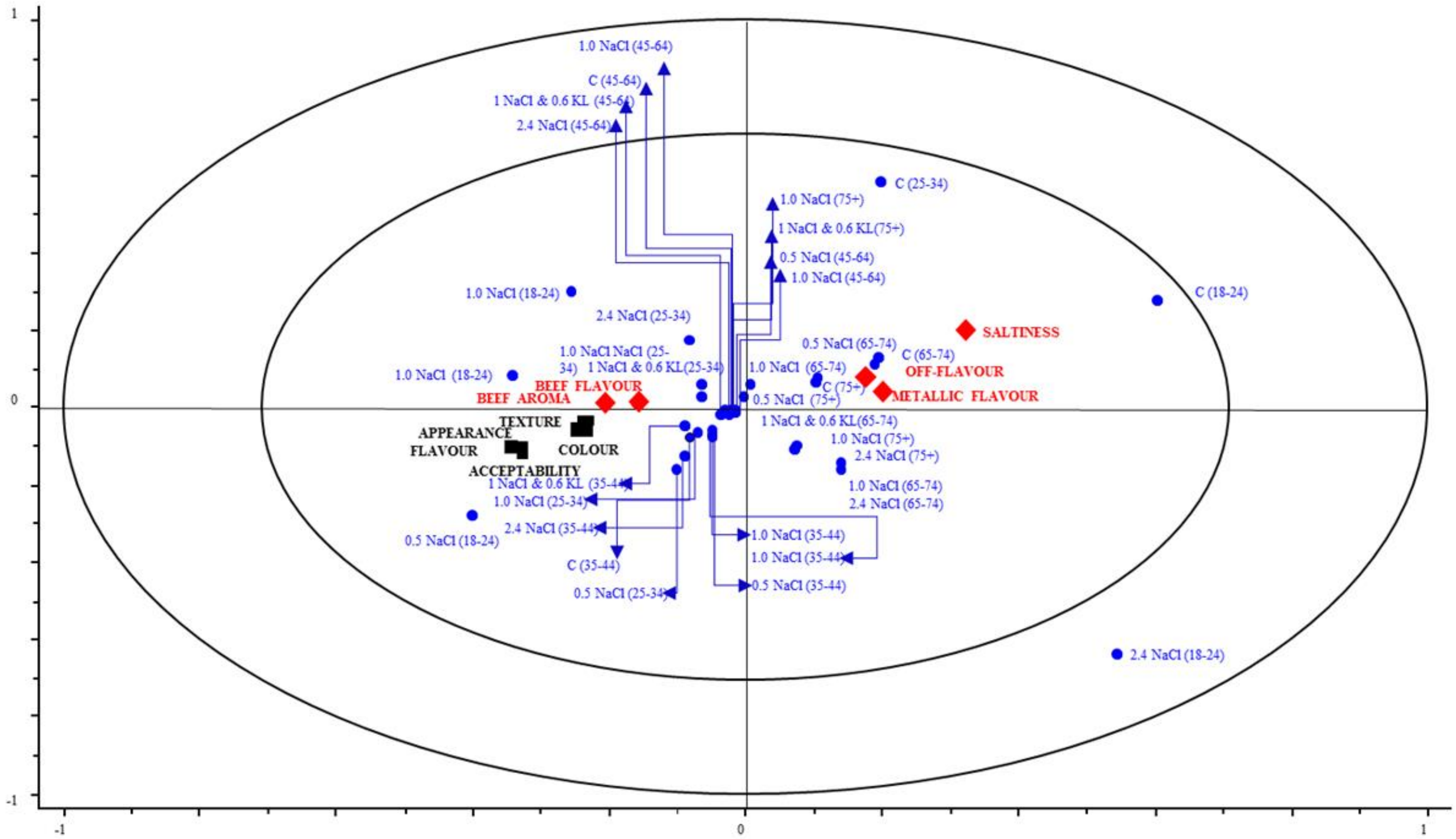

Figure 1: ANOVA - partial least squares regression (APLSR) correlation loading plot for each individual treatment, age category and sensory descriptor and intensity rating (PC1 Vs PC2)

There were extremely dynamic observations noted in the sensory testing among the age cohorts for the control sample, thereby suggesting that the current commercial corned beef on the market may not appeal to all assessors. The sample most negatively perceived was the control sample, thereby suggesting that the levels of NaCl added to commercial corned beef is currently too high for assessors' acceptance, and in some incidences, beef flavour was not noted but an off-flavour was.

Corned beef samples containing 1.5% NaCl (Table 4.6) in the final product featured a reduction of NaCl closest to the FSA 2012/2017 guidelines (reducing NaCl levels to 1.63g/100g in corned beef). The 35-44 age group liked the appearance and flavour of the sample containing 1.5% NaCl ($P \leq 0.01$) and ($P \leq 0.01$), respectively (Table 4.4). This age group did not link the sample containing 1.5% NaCl with either off-flavour ($P \leq 0.05$) or metallic flavour ($P \leq 0.01$) (Table 4.5). The 65-74 age group did not like samples containing 1.5% NaCl for appearance ($P \leq 0.01$) and flavour ($P \leq 0.05$) (Table 4.4). They did not link this sample with beef flavour ($P \leq 0.05$), but they did associate it with having a metallic flavour ($P \leq 0.01$) (Table 4.5). There was no metallic flavour noted in this sample by the other age cohorts. There has been many attempts to encourage people to change to more healthy diet, however, significant changes are unlikely, particularly as people increase in age according to Devine, Connors, Bisogni, & Sobal, (1998) or have already developed a preference for their own traditional foods (Laureati, Pagliarini, Calcinoni, & Bidoglio, 2006). It is therefore difficult to identify the type of policies that may work, as some researchers report changes in behaviour whilst others do not (Capacci et al., 2012). In a study examining how perceptions of food quality are explained by demographic and socio-economic features at the individual level, it was found that that women, older and more educated individuals are more interested in calories, safety and taste of food (Baiardi, Puglisi, & Scabrosetti, 2016). Thus, a reduction to 1.63% of NaCl in processed or cured meats is achievable without inducing off-flavours or metallic flavours. A reduction of 1.63% of NaCl in the present study did not negatively impact the flavour for all age cohorts, except for the 65-74 age cohort.

The corned beef sample containing 1.0% NaCl in the final product included the same NaCl as the sample containing 1.0% NaCl & 0.6% potassium lactate, as can be seen in Table 4.6. These samples had the closest NaCl level to the WHO salt targets (WHO, 2010) which recommends a reduction to 1.35g/100g salt in corned beef. The 18-24 age category liked the sample containing 1.0% NaCl and no potassium lactate for flavour, colour and acceptability ($P \leq 0.05$), ($P \leq 0.05$) and ($P \leq 0.01$), respectively (Table 4.4). The 25-34 age category liked this sample for both appearance and flavour ($P \leq 0.05$) (Table 4.4). They also associated this same sample as having a beef flavour ($P \leq 0.05$) (Table 4.5). The 35-44 age cohort linked the sample containing 1.0% NaCl for both appearance and flavour ($P \leq 0.01$) (Table 4.4). This age cohort did not associate this sample with having an off-flavour ($P \leq 0.01$) or a metallic flavour ($P \leq 0.05$) (Table 4.5). The 45-64 age group liked the flavour of this sample ($P \leq 0.05$) (Table 4.4), and did not perceive off-flavours with this sample ($P \leq 0.05$) (Table 4.5). There were no major sensory differences noted between the sample containing potassium lactate (1.0% NaCl & 0.6% potassium lactate) and that without potassium lactate (1.0% NaCl). Thus, potassium lactate may be added to corned beef without effecting sensory results, whilst increasing the health benefits (FSAI, 2015) associated with potassium. In a socio-demographic and attitudinal study examining the consumer's willingness to compromise on taste for health in functional foods, the authors found that that the gap between the acceptances of good versus the worst tasting functional foods has changed significantly from 2001 to 2004. Females and elderly were readier to compromise on taste for health in 2001, any socio-demographic differences became redundant by 2004. Thus, the health benefits associated with functional foods emerges as the strongest positive determinant of willingness to compromise on taste (Verbeke, 2006). Consumer's attitudes towards foods are constantly changing and developing. Belief in the health benefits of functional foods is the main positive determinant of acceptance (Verbeke, 2005).

As can be seen in Fig 1., the corned beef sample containing 1.0% NaCl was associated with off-flavour and metallic flavour by the senior citizen age cohorts (65 yrs old and over). However as can be seen from Table 4.5, this perception was not significant. All the age cohorts examined in this study, with the exception of the 65-74 age cohort accepted the flavour attribute of the corned beef with the closest salt level to the FSA target (1.0% NaCl). Food neophobia is often common in senior citizen assessors. It is defined as the reluctance to try novel foods (Pliner & Hobden, 1992). Taste has been proven to be a more important factor in deciding assessors preference for food products in older age cohorts compared to younger ones (Kälviäinen, Roininen, & Tuorila, 2003a). One study examined the different effects of various flavour amplification on soup, Quorn® and yoghurt on preference and consumption in young and elderly subjects. Test subjects aged 60 years or more (n=20) and healthy young person's 20-30 years (n=16) were examined. The majority of the younger subjects were found to prefer the low favour soup, Quorn® and yoghurt, while the elderly subjects preferred the high favour level soup, Quorn® and yoghurt. The authors concluded that flavour amplification of food for the elderly deserves attention and regular consumption of such manipulated food products would consequently improve nutritional status (Kälviäinen, Roininen, & Tuorila, 2003).

The corned beef sample containing 0.5% salt contained the lowest NaCl formulation in this trial. The 35-44 age group liked this sample for appearance, flavour and texture ($P \leq 0.05$), ($P \leq 0.01$) ($P \leq 0.05$), respectively (Table 4.4). They also associated this sample with having a beef aroma ($P \leq 0.05$) but did not associate it with having an off-flavour ($P \leq 0.01$) (Table 4.5). The 45-64 age group did not associate sample (0.5% NaCl) with off-flavour ($P \leq 0.05$). This sample was perceived differently among the various age cohorts. Fig. 4.1. illustrates how the sample is spread out over three quadrants of the APLSR plot. The younger age cohorts: 18-24, 25-34 and 35-44 liked this sample (as can be seen on the left-hand side of the diagram). In contrast, the 45-64, 65-74 and the 75+ age categories disliked the samples (as can be seen on the right-hand side of the diagram) by describing the samples as being salty, possessing off-flavour and possessing metallic flavour. Previous studies have found that salt taste, juiciness and texture were the sensory parameters most affected by NaCl reduction (Aaslyng, Vestergaard, & Koch, 2014). As this sample featured a lower NaCl level recommended by the WHO and FSA salt targets, it illustrates the possibility of reducing these targets further, particularly for younger consumers. Overall the most dynamic sensory results were observed for the sample containing the highest NaCl level (2.4 % NaCl) and the sample containing the lowest NaCl level (0.5 % NaCl). The youngest age cohort (18-24) disliked the sample containing the most salt whereas the senior citizen age cohorts did not notice any difference in that sample compared to the others. Varying sensory preferences were noted among assessors of different age cohorts throughout this study.

4.7.2 Proximal Compositional Analysis

The Proximal compositional analysis results obtained in this study are presented in Table 4.6.

The samples ranged in fat content from (2.5-4.4%) these values are much lower than those recorded in other salted beef products, as the fat was initially removed to standardise the beef pieces used in this study. The UK Mc Cance and Widdowson database recorded a fat content of 7.0% in its lean beef samples (Mc Cance and Widdowson, 2005). Moisture content varied significantly among samples. The corned beef sample containing 1.0% NaCl & 0.6% potassium lactate and that containing 1.0% NaCl had the same NaCl content and it was the same in terms of moisture content.

Even though the results were non-significant, the moisture content of corned beef containing 1.0% NaCl & 0.6% potassium lactate was lower than that of the meat sample containing only 1.0% NaCl. In a previous salt replacement study, it was found that potassium lactate reduced the moisture content (P<0.05) of products, thereby increasing the preservative effect of potassium lactate (Choi & Chin, 2003). Therefore, this corresponds well with a mechanistic explanation of how the addition of potassium lactate reduces the growth of microbes in meat products. There were no significant differences observed in carbohydrate values. This result was expected as no extra carbohydrates were added to the meat at any stage of production. NaCl values were not significantly different in corned beef samples containing 1.0% NaCl & 0.6% potassium lactate and 1.0% NaCl. Both meat samples had 1.0% NaCl. The remainder of the samples differed in their NaCl content significantly. As expected, potassium lactate values did not differ, apart from that meat sample containing KI (1.0 NaCl & 0.6 potassium lactate). Corned beef samples containing 1.0% NaCl & 0.6% K and 1.0% NaCl did not differ in terms of ash content.

4.7.3 Physiochemical Analysis

The corned beef samples containing 1.0% NaCl & 0.6% potassium lactate and 1.0% NaCl with no added potassium lactate both contained 1.0% NaCl when physiochemical analysis was carried out (Table 4.6). The beef sample which contained 1.0% NaCl & 0.6% potassium lactate did contain potassium lactate, whereas sample (1.0% NaCl) did not contain any as expected. Regarding sensory analysis, no age group associated any of these samples with negative attributes; off-flavour and metallic flavour. However, regarding physiochemical analysis (Table 4.7) corned beef samples containing 1.0% NaCl & 0.6% potassium lactate was significantly lighter in colour than samples containing 1.0% NaCl. The corned beef samples containing 1.0% NaCl & 0.6% potassium lactate had significantly lower values for a* and b* than samples containing only 1.0% NaCl. The addition of potassium lactate affected the colour of the corned beef. The sensory consumer test did not record any differences in colour between the two samples. No significant differences were noted between the corned beef samples which contained 1.0% NaCl & 0.6% potassium lactate and the sample containing 1.0% NaCl when cohesiveness and resilience were measured. In a salt reduction study NaCl in fermented sausages was substituted using levels higher than 30% of potassium lactate, potassium chloride, and glycine. A loss of cohesiveness was noted following sensory analysis in the NaCl substituted samples (Gou, Guerrero, Gelabert, & Arnau, 1996). This current study did not utilise a complete salt replacer this may account for the lack of cohesiveness differences observed from TPA analysis. The cooking loss result of the sample containing potassium lactate was lower than the other samples not containing potassium lactate. Due to its hygroscopisity, potassium lactate has a positive effect on a products water holding capacity, which may result in less purge, a higher cook yield and an improved texture for cooked product (Shelef, 1994).

4.8 Conclusion

The tailoring of food formulation to cater for different sensory preferences amongst different age groups presents a potential untapped market for the meat industry. Variations in taste, texture and mouth feel may be produced by adding various salt replacers to cured meats which cater for different sensory preferences by different consuming age cohorts. Potassium lactate may be added to meats as a salt replacer without influencing the sensory qualities for certain age groups. This study adds to the already existing evidence that age-related differences in sensory acceptance of foods exists.

The reformulation of common foods is a positive step in achieving certain public health interventions. However, it is essential that these foods are accepted by the consumer and meets their sensory expectations when reformulating them. Not all food products need the high level of salt that is added during processing to gain consumer acceptability, as demonstrated in this study. This research provides evidence for the acceptance of assessors for the FSA and WHO salt targets in processed foods in certain age cohorts. The samples that featured a NaCl reduction level like the FSA and the WHO NaCl reduction recommendations were positively perceived among all age cohorts, but not within the senior citizen age bracket (≥64 yrs. old). This study demonstrates an acceptance for a salt level as low as 0.5% NaCl in corned beef for those consumers aged under 45 years of age.

The youngest age cohort (18-24) disliked corned beef samples containing the highest level of NaCl, whereas the oldest age cohorts (≥ 65 yrs. old) did not notice any significant difference between samples. No differences were observed in the ≥ 65 yrs. old age cohort between the sample containing potassium lactate and that not containing potassium lactate. Thus, it may be possible to manipulate processed meats that contain potassium lactate without influencing the sensory perception of the senior age cohorts, while incurring added health benefits. Food tailored to the elderly consumer is a valuable approach to targeting malnutrition due to sensory perception decline in this age cohort.

Assessors of varying age groups have differing preferences for certain NaCl levels and salt replacers. As previously stated assessors consume varying levels of salt according to their age cohort and gender. The meat industry could explore various possibilities, including the control of the raw and processed materials to produce bespoke design foods reformulated to cater for public health needs. The onus is on the food industry to facilitate convenient healthier food products with an emphasis on sensory acceptance for its different consumer segments.

CHAPTER 5

Impact on the physical and sensory properties of salt-and fat-reduced traditional Irish breakfast sausages on various age cohorts acceptance

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Abstract

The properties of varying salt and fat levels in traditional breakfast sausages were investigated. Sausages were produced with fat levels of: 30%, 20% and 15%. Fat was replaced with pea extract. Salt levels employed were: 2.5%, 1.1% and 0.0%. A reduced sodium salt which contains 45% less sodium than standard salt was used. Sensory analysis was conducted on consumers (n=228): 18-40 yrs., 41-64 yrs. and 65-85 yrs. The 18-40 yr. olds preferred sausages containing 20% fat, 41-64 yr. olds preferred sausages with 15% fat, 65+ age group preferred sausages containing 30% fat. The 18-40 yr. olds preferred high salt samples, 41-64 yr. olds displayed no salt preference, while the 65+ age group preferred high salt sausages. Sausage formulation choice was found to be driven by texture for the younger age cohort, flavour for the middle age cohort and visual aspects from the oldest age cohort. There is a need to understand how meat products might be reformulated for different age palates.

Key Words: Fat Reduction; Salt Reduction; Sensory; The elderly.

1. Introduction

Due to the increasing number of the elderly consumers in Europe, knowledge pertaining to their health and nutritional status should be complemented by studies focused on food preferences. Nutritional status and health of older adults has a direct impact on their social and economic interactions. Health concerns associated with processed meat products has become topical in recent years. Traditional Irish meat products such as breakfast sausages are familiar to all Irish age groups. While such products are useful in that they offer a protein source through the utilisation of meat off-cuts and trimmings, such products are typically comprised of high percentages of fat (Keenan, Resconi, Kerry, & Hamill, 2014) and salt (Fellendorf, O'Sullivan, & Kerry, 2015) and thus raise concern in relation to associated health risks through consumption. According to IUNA (2011), 39% of the Irish population aged between 18-64 years of age consume sausages and 31% of those 65 years old and over consume sausages. Taste (41%) was the most important factor for Irish consumers purchasing a product, followed by health and nutrition (36%).

The WHO (2012) recommends that adults should consume less than 2000mg of sodium, or 5g/d of salt. The Food Standards Agency Salt Targets 2017 are 1.3g of salt or 450mg of sodium in sausages. Previous researchers have successfully reduced salt in processed meats without compromising on sensory quality (Tobin et al., 2013; Fellendorf et al., 2015; Fellendorf, O'Sullivan & Kerry, 2017; Fellendorf, Kerry, Hamill & O'Sullivan, 2018; Delgado-Pando et al., 2018). Reductions in salt may be of huge benefit to the elderly. In a trial involving men and women aged 60–78 years of age, a decrease in daily salt intake from 10g to 5g for one month was linked to an average fall in SBP (systolic blood pressure) of 7mmHg and that these effects, which were seen in normotensive and hypertensive subjects, resulted in a 36% reduction rate in stroke risk over a five-year period in this age group (Cappuccio, Cook, Atkinson, & Strazzullo, 1997). The demand for low salt food products has resulted in reduced salt content meat products being available commercially. A variety of approaches to replace or substitute sodium chloride are available for meat processing, which includes using; transglutaminase (TG), potassium chloride (KCl), dietary fibre, and caseinate as a salt replacer (Colmenero, Ayo, & Carballo, 2005). Processed meats generally have the highest fat content (approximately 25%) of all meat categories (Chan, Brown, Church, & Buss, 1996). Fat is incorporated into processed meat products, as fat possesses unique and important sensory characteristics as its presence in products affects mouth-feel, juiciness and taste. Fat also plays an important structural role in meat products (Cáceres, García, & Selgas, 2008). However, fat in processed meats poses a threat to public health as it may increase the risk of diseases like CVD, obesity and cancer. This is mostly due to its high saturated fat content (WHO, 2008). Loss of sensory perception of fat increases with age (Schiffman, Graham, Sattely-Miller, & Warwick, 1998). This may further increase the danger of over consumption of high-fat foods by the elderly to compensate for their lower capacity to perceive fat in foods. Strategies for reducing fat in processed food products have been devised. Fat substitutes like rice starch, (Limberger et al., 2011), milk-co-precipitate, (Eswarapragada, Reddy, & Prabhakar, 2010), soy protein isolate, (Chin, Keeton, Miller, Longnecker, & Lamkey, 2000), pea flour, starch and fibre (Pietrasik & Janz, 2010) have been employed for use in processed meats.

Increased quantities of fibre in foods have been proven to reduce the risk of colon cancer, cardiovascular diseases, obesity, and several other disorders (Cummings, Bingham, Heaton, & Eastwood, 1992; & Johnson & Southgate, 1994). The hulls of yellow peas are comprised of approximately 82% fibre making them an excellent fibre source for incorporation into food products Ribéreau, Aryee, Tanvier, Han, & Boye (2018). In metabolically unhealthy humans, 12g/d of pea fibre intake for 28 days reduced fasting insulin concentrations and improved postprandial glucose responses (Marinangeli & Jones 2011). Pea fibre has also been proven to be beneficial from a function ability (Grigelmo-Miguelet et al. 1999) and nutritional point of view (Rossellet et al. 2001). In a study examining the effect pea fibre had on beef burgers it was found that the water-holding capacity of raw beef burger was significantly higher due to the addition of pea fibre. The use of pea fibre in the beef burger reduced the cook loss and in turn it decreased the shrinkage. Many dietary fibres have been used in meat products, not only to determine their possible beneficial effects on health, but also as potential fat substitutes (Chang & Carpenter, 1997; & Mansour & Khalil, 1997).

Processed meats are especially desirable to the elderly consumers as they generally tend to be traditional product-types, possess high fat and salt levels which satisfy sensory desirability by overcoming perceptional decline and are protein dense. Despite all that has been described above, little or no research has been conducted into examining the sensory impacts that fat and salt reduction in breakfast sausages would have on different age cohorts of consumers.

Consequently, the objective of this study was to investigate age related sensory perception because of substituting fat and salt with pea extract and a reduced sodium salt, by examining the sensory perception of sausages based on varying age cohorts. It was envisaged that this research may provide an insight into sensory decline with age, and provide suggestions as to more healthful substitutes for the traditional breakfast sausage. The scientific objective of this research focused on establishing a profile of formulations which are accepted based on differing age cohorts with the aim of identifying perceived differences as aging occurs.

2. Materials and Methods

2.1 Reagents and chemicals

Sulphuric acid, hydrogen peroxide, boric acid, hydrochloric acid, sodium hydroxide and silver nitrate were supplied by Sigma-Aldrich Ireland Ltd., Vale Road, Arklow, Wicklow, Ireland.

2.2 Sample Preparation

Fresh boneless pork and pork back fat was purchased from local meat processors (Ballyburden Meats Ltd, Ballincollig, Cork, Ireland). All meat purchased had full traceability. The meat and fat were cut, weighed and placed into vacuum packs and vacuum packaged. They were then and stored in the freezer (-18°C) until required. Prior to use meat and fat were thawed slightly at refrigerated temperature (4°C) before being minced through a 10mm plate (TALSABELL S. A.,Pol. Ind. V. Salud, 8. Valencia, Spain). Independent batches of pork and pork fat was used each time. The ingredients were weighed according to the formulations in Table 5.1. The reduced sodium salt, and pea extract were purchased from All in All Ingredients Ltd., Unit 33 Lavery Avenue, Parkwest, Dublin 12, Ireland. The reduced sodium salt was measured by the manufacturer 'All in All Ingredients' to determine that the salt contained 45% less sodium than standard salts. The reduced sodium salt featured the following composition. Sodium: 22.0 ± 0.6, chloride: 34.0 ± 0.9, sulphate: 23.0 ± 0.7, potassium: 9.0 ± 0.3, magnesium: 2.0 ± 0.1, trace elements 0.3± 0.1 & free and bound moisture: 10.0 ± 1.5. The seasoning utilised is a 0% salt spice blend: which is described as having yeast extract, carmine, sodium ascorbate and sodium metabisulphate. The seasoning was supplied by All in All ingredients also. The mix comprised of the pork, seasoning (0% sodium), salt, pea starch, the reduced sodium salt and a third of the required water were fed into a bowel chopper and mixed at high speed for 45s.

Having formed the base emulsion, the required fat was then added to the bowel chopper (Maschinenfabrik Seydelmann KG, Aalen (Wurtt), Burgstallstrabe, Germany) and the mix was chopped for a further 45s at high speed. The remaining water was added and the batter mixed for a further 30s. at high speed. Finally, the pin-head rusk was added to the batter and mixed again for 30s at low speed. The sausage mix was then loaded into the sausage filler, (Mainca, Mod EB 12/25 MAINCA, Maquinaria Industria Carnica Equipamientos Carnicos, S.L. Granollers, Barcelona, Spain) from where it was fed into collagen casings. The sausages were the sealed in plastic bags and refrigerated (4°C) overnight to allow product equilibration. Nine treatment batches were manufactured three individual times as can be seen in Table 5.1.

2.3 Cooking

Oven cooking of the sausages was chosen as the cooking method as it provided consistent results and was easily replicated. Each sausage sample was wrapped in aluminium foil (tin-foil), labelled and dry cooked at 150°C in a Zanussi convection oven (C. Batassi, Conegliano, Italy) and cooked to an internal temperature of 73°C, as monitored using a calibrated temperature probe (Testo 110, Lenzkirch. Germany).

Table 5.1: Sausage Formulations

%	C	RNa1,N0,0.1	RNa1,N0,0.2	RNa1,N0,0.3	RNa0,N1,0.1	RNa0,N1,0.2	RNa0,N1,0.3	RNa0,N0,0.1	RNa0,N0,0.2	RNa0,N0,0.3
MSG	0	0.1	0.2	0.3	0.1	0.2	0.3	0.1	0.2	0.3
NaCl	2.5	0	0	0	1	1	1	0	0	0
RNa	0	1	1	1	0	0	0	0	0	0
Fat	30	15	15	15	15	15	15	15	15	15
Pea	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pork	35	35	35	35	35	35	35	35	35	35
Rusk	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Seasoning	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Water	17.5	33.4	33.3	33.2	33.4	33.3	33.2	34.4	34.3	34.2

C = Control, RNa = Reduced Sodium Salt, N = NaCl, MSG = Monosodium Glutamate

2.4 Sensory Analysis

2.4.1 Recruitment

Panellists of varying age cohorts were recruited for this study. Panellists were chosen in compliance with the following criteria; community dwelling, healthy, did not have a food allergy, did not have any difficulties swallowing, and were regular consumers of breakfast sausages. Trial subjects were recruited from University College Cork and from active retirement groups based around the Cork region to allow for an older consuming demographic within the study. The assessor cohorts were derived from various socio-economic backgrounds and were gender balanced.

2.4.2 Sensory Evaluation

Sensory analysis was carried out on untrained assessors (n=228). The ages ranged from 18-85 yrs. of age. The sample size of the three age cohorts were 18-40 yrs. (n=81), 41-64 yrs. (n=84) and 65-85 yrs. (n=63). Consumers evaluated both hedonic (n=4), first and then intensity (n=7) attributes at the same session, but separated by an interval to allow training and descriptor explanation with reference to a provided table of description. The definitions presented to each panellist are outlined in Table 2. Nine products were evaluated per session and two sessions were carried out per consumer. Each panellist rated the sensory qualities of the samples according to AMSA (1995). The following hedonic (liking) attributes were examined always first; texture, flavour and acceptability. Hedonic attributes were rated whereby 0=extremely dislike 8=extremely like. The following intensity attributes were then measured after a short training session whereby descriptors were presented along with a table of description: Spiciness, coarseness, toughness, juiciness, meat flavour, off flavour and saltiness. Intensity was rated whereby 0=none 8=extreme. The samples were presented to the assessors on a white polystyrene plate. Each sample was presented randomly, with corresponding codes on the plate. The panellists were asked to rinse their mouths with water in-between each sample in accordance with the methods of (Tobin et al., 2012b). The experiment was conducted in panel booths, which conformed to international standards (ISO, 2007).

Table 5.2: Reduced Sodium Salt Composition

Ingredient	**Composition g/100g**
Sodium	22.0 ± 0.6
Chloride	34.0 ± 0.9
Sulphate	23.0 ± 0.7
Potassium	9.0 ± 0.3
Magnesium	2.0 ± 0.1
Trace Elements	0.3 ± 0.0
Free and bound moisture	10.0 ± 1.5

Ingredient levels in the 45% reduced salt blend

Table 5.3: Significance of relationships between sensory descriptors, fixed (treatment, age and treatment*age interaction) and random factors (session, batch and panellist)

Sensory	Texture	Saltiness	Spiciness	Flavour	Colour	Acceptability	Coarseness	Toughness	Juiciness	Meat flavour	Off flavour
Treatment	0.155 ^{ns}	0.663 ^{ns}	0.061 ^{ns}	0.650 ^{ns}	0.565 ^{ns}	0.091 ^{ns}	0.252 ^{ns}	0.001***	0.546 ^{ns}	0.879 ^{ns}	0.149
Age	0.004**	0.000***	0.000***	0.194 ^{ns}	0.000***	0.000***	0.001***	0.003**	0.076 ^{ns}	0.000***	0.004
Age * Treatment	0.933 ^{ns}	0.340 ^{ns}	0.233 ^{ns}	0.763 ^{ns}	0.232 ^{ns}	0.502 ^{ns}	0.563 ^{ns}	0.961 ^{ns}	0.671 ^{ns}	0.593 ^{ns}	0.994
Session	0.000***	0.000***	0.000***	0.933 ^{ns}	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0
Batch	0.746 ^{ns}	0.047 ^{ns}	0.249 ^{ns}	0.492 ^{ns}	0.534 ^{ns}	0.850 ^{ns}	0.847 ^{ns}	0.600 ^{ns}	0.937 ^{ns}	0.598 ^{ns}	0.999
Panellist	0.000***	0.000***	0.000***	0.075 ^{ns}	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0

Significance of regression coefficients; ^{ns} = non-significant, * = ($P \leq 0.05$), ** = ($P \leq 0.01$), *** = ($P \leq 0.001$)

2.5 Proximate Compositional Analysis

2.5.1 Protein Content

The Kjeldahl method, was used to determine the protein in the cooked breakfast sausage samples (Suhre, Corrao, Glover, & Malanoski, 1982), and percentage protein was calculated using a nitrogen conversion factor of 6.25. This method was in accordance with the work outlined by (Tobin et al., 2013). The results recorded represent the average of six measurements (three independent batches x two samples).

2.5.2 Ash Content

Ash content of the sausages were measured using a muffle furnace (Nabertherm GmbH, Lilienthal, Germany). The muffle furnace was preheated to 525°C. A 5g blended sample was weighted into a porcelain dish and placed in the muffle furnace for 6 hr, until the colour of the samples went white. The samples were placed in a desiccator to cool. The dishes were weighted and the ash content was calculated. The results recorded represent the average of six measurements (three independent batches x two samples).

2.5.3 Moisture and Fat Content

A 2.0g of sausage sample was homogenised using a Büchi Mixer B-400 (Büchi Labortechnik AG, Meierseggstrasse 40, Postfach, CH-9230 Flawil 1, Switzerland). The sample was transferred into a moisture proof bag, to ensure that the least amount of moisture as possible was lost. The moisture content was then determined using the CEM SMART system and the fat was determined using the SMART Trac system (CEM GmnH, Kamp – Lintfort, Germany).

The results recorded represent the average of six measurements (three independent batches x two samples).

2.5.4 Carbohydrates

Total carbohydrates were determined by difference: A hundred grams minus the addition of protein, fat, water and ash in grams, expressed as a percentage. The results recorded represent the average of six measurements (three independent batches x two samples).

2.6 Physical Analysis

2.6.1 Texture Analysis

After cooking, sausage samples were cooled to room temperature (approximately 20°C) to determine textural properties. Texture was measured using a texture profile analyser; (Texture Analyser 16 TA-XT2I Stable Micro Systems, Surrey, UK) following the guidelines of AMSA 1995 procedures. Cylindrical slices (10mm x 10mm) were taken from each sausage. Each slice underwent a two cycle compression test using a 25kg load cell. The samples were compressed to 40% of their original height with a 35mm diameter probe (SMSP/35 compression plate) and a cross head speed of 1.5mm/s.

Textural factors were measured using descriptors highlighted by Bourne, (1978). They included springiness (mm): the samples' ability to recover its original shape after the initial compression and the deforming force were removed, cohesiveness (dimensionless): extent to which the sample could be deformed prior to rupture, measured by the areas under the compression portion instead of using the total area under positive force, hardness (N): maximum force required for the initial compression of the sample and resilience (dimensionless): the ratio between the negative force input to positive force input during the first compression. The results recorded represent the average of six measurements (three independent batches x two samples).

2.6.2 Colour

Surface colour was measured on the cooked sausages. The sausages were brought to room temperature (approximately 20°C) before analysis. The sausages were cut down the middle before being analysed through colourimetry (Minolta Camera Co. Ltd., Osaka, Japan).

Lightness (CIE), redness (a ± red-green) and yellowness (b ± yellow-blue) were measured. A CIE 19312º standard observer was used. The colourimeter features an 11mm – diameter aperture and D65 illuminant, calibrated by the CIE Lab colour space system using a white tile (C: y=93.6, x=0.3130, y=0.3193). A Minolta calibration plate was used to calibrate the instrument. Colour was measured by following the guidelines for colour measurements presented by the AMSA (2012). Duplicate colour measurements were recorded on two samples from each experimental batch.

2.6.3 Cooking Loss

Sausage sample weights were recorded both before and after cooking. The differences in weights were recorded. Each sample was wrapped in aluminium foil before cooking. Before weighing, each sample was blotted with a paper towel to remove excess moisture. Cooking loss was determined as the difference between cooked and raw weights expressed as a percentage of the raw weight. The results recorded represent the average of six measurements (three independent batches x two samples).

2.7 Chemical analysis

2.7.1 Salt

The salt concentrations were measured in accordance with that reported Fox (1963). The samples were homogenised thoroughly. A 2g of sample of sausage meat was added to 100ml of dilute nitric acid solution (1.5ml conc. Nitric acid/L).

Samples were placed in a water bath at 60°C for 15mins. The sample was then titrated with 0.1M $AgNO_3$ to +255mV using a potentiometer equipped with silver and reference electrodes. During titration, a magnetic stirrer was used to assist solution mixing. A bank titration was also carried out. By means of the ratio to chloride, sodium chloride concentrations were calculated. The results recorded represent the average of six measurements (three independent batches x two samples).

2.8 Statistical Analysis

Data obtained from the sensory trials were analysed using ANOVA – Partial Least Squares Regression (APLSR) to process the mean data accumulated from the test subjects. Data was processed using Unscrambler software version 10.3. (CAMO ASA, Trondheim, Norway). The X-matrix was designed as different age categories. The Y – matrix involved the sensory, variables of the design. The fixed effects were age cohorts and the random effects were sensory results and sausage samples. Principal components i.e. PC 1 versus PC 2 are presented (Fig. 5.1). Regression coefficients were analysed by Jack – knifing (Table 5.4) to derive significant indicators for the relationships determined in the quantitative APLSR, which is based on cross validation and stability plots.

A mixed model ANOVA was conducted in SPSS. The age*treatment interaction was measured. The fixed effects included treatments and panellist's ages. The batches, panellists and sessions were included as random effects. All datasets were subjected to descriptive analysis and tests for normality (Shapiro-Wilk test), Independence and Equality of Variances (Levene's test) were performed. The assumptions of the relevant statistical tests were satisfied in all cases. Tukeys HSD post hoc test was used to determine significant differences within the groups. The results can be viewed in Table 3. Proximate (Table 5.5) and physical (Table 5.6) data are presented as the mean values ± standard error of the mean (SEM). One-way ANOVA was used to examine the data from proximate and physical analysis. Tukey's post-hoc test was used to adjust for multiple comparisons between treatment means using. All statistical analysis was carried out using the SPSS 11.0 software package for Windows (SPSS, Chicago, IL, USA).

3. Results and discussion

3.1 Fat and Pea extract

The interactions between sensory results on treatment, age, session, batch and panellists is illustrated in Table 5.3. As expected age and panellists both caused significant effects on the sensory analysis results. The results of the breakfast sausage consumer sensory evaluation (n=228) can be viewed in Table 5.4. The sensory data figures are presented in the PCA plot in Fig. 5.1. From this plot it can be seen that the 18-40 yr. olds focused on texture attributes such as coarseness, texture and toughness. The 41-65 yr. olds were associated predominantly with flavour attributes such as flavour, meat flavour and spiciness. The 65+ age cohort were more focused on the visual presentation of the sausages. They focused more on colour than the other age cohorts.

Table 5.4 presents the 18-40 year old age group as accepting the samples containing 20% fat; (F20,S0,RNa1.13) ($P \leq 0.01$), (F20,S1,RNa0) ($P \leq 0.001$) and (F20,S0,RNa1) ($P \leq 0.001$). There were trends towards negative correlations for the acceptability of the 15% fat sausages. This age group statistically ($P \leq 0.01$) did not accept the lower fat sample; (F15,S0,RNa1) for meat flavour. The 41-64 year old age group accepted the sausages containing 15% fat; (F15,S0,RNa1.13) ($P \leq 0.001$), (F15,S1.13,RNa0) ($P \leq 0.05$) and (F15,S0,RNa1) ($P \leq 0.01$).

Panellists aged between 18-40 years of age preferred sausages formulated with 20% ((F20,S0,RNa1.13) ($P \leq 0.01$), (F20,S1,RNa0) ($P \leq 0.001$) and (F20,S0,RNa1) ($P \leq 0.001$) over those formulated with 15% fat and which were deemed to be unacceptable by this age cohort on the basis of meat flavour. However, panellists aged between 41-64 years of age had a greater acceptance for sausages containing 15% fat ((F15,S0,RNa1.13) ($P \leq 0.001$), (F15,S1.13,RNa0) ($P \leq 0.05$) and (F15,S0,RNa1) ($P \leq 0.01$)) as can be seen in Table 5.4.

Panellists in the 65+ age category only had a trend towards acceptance for the control sample (F30,S2.5,RNa0). This had the highest fat in all of the sausage formulations. Similar results were observed in the research of Schiffman et al. (1998), who also found the elderly require a higher amount of fat to detect its presence. It was found that fat detection thresholds ranged from 5.3% (vol/vol) in young adults to 15.8% (vol/vol) in the elderly (Schiffman, et al., 1998). Panellists in the 65+ age group disliked the reduced fat sample (F20,S0,RNa1) ($P \leq 0.001$). This was due to a dislike for the products texture ($P \leq 0.001$). In a study carried out by Rolls et al., (1997) it was found that the elderly consumers rated the sensory properties of fat, such as taste and texture as major determinants when consuming foods. However, this finding does not agree with the results of (Warwick & Schiffman, 1990) who found that fat content did not influence the elderly's perception of foods. In this study the 18-40 year olds preferred the 20% sausages, the 41-64 year olds preferred the 15% fat sausages and the 65+ age group preferred the 30% fat sausage.

The control sample (F30,S2.5,RNa0) was linked with saltiness ($P \leq 0.001$), spiciness ($P \leq 0.01$) and meat flavour ($P \leq 0.01$) by the 65+ age group. High fat is hypothesised to enhance meaty flavour (Keeton, 1994). The reduced fat samples (F15,S0,RNa1), (F15,S1.13,RNa0), (F20,S0,RNa1.13) and (F20,S1.13,RNa0) were not perceived as having a coarse texture by the 65+ age cohort, whereas the control sample was associated with a coarse texture. This result was unexpected as fat is thought to induce a lubricated texture to meats and meat products. Chapter 3 has shown a decrease in textural acuity in those over the age of 65.

Colour which was rated 'extremely dislike' to 'extremely like' was perceived very differently among the three age groups. The 18-40 age cohort did not like the colour of the samples containing 20% fat: (F20,S0,RNa1.13) ($P \leq 0.01$), (F20,S1,RNa0) ($P \leq 0.001$) and (F20,S0,RNa1) ($P \leq 0.001$). They had a preference for one of the samples containing 15% fat; (F15,S0,RNa1) ($P \leq 0.001$). The 41-65 age group disliked the samples containing 15% fat for colour: (F15,S0,RNa1.13) (*P*≤0.001), (F15,S0,RNa1) (*P*≤0.01) and (F15,S1.13,RNa0) (*P*≤0.01). These results disagree with those of Chan & Kane-Martinelli., (1997) who examined the effect of food colouring on perceived flavour intensity and acceptability ratings in samples of chicken bouillon and chocolate pudding. These foods were presented with no colour added, with the normal level of food colouring, or with twice the normal level of colour added. The results indicated that younger adults (20 to 35 years of age) were more affected by the presence of food colouring than the older adults (60 to 90 years of age). The younger age group's judgment of the overall flavour intensity of the chicken bouillon was influenced by the quantity of colouring added to the sample (Chan & Kane-Martinelli, 1997). The senior citizen age cohort: the 65+ age group favoured the colour of all samples particularly sample (F20,S1.13,RNa0) (*P*≤0.05). However, this was not the case for the control sample. In this study the younger adults (18-40) inversely associated colour with acceptability.

Pea extract was only absent from the control group. There are no indications that this affected the acceptability of the sausages for the 18-40 or the 41-64 age groups. Similar results can be observed in the work of Pietrasik & Janz, where consumer acceptance of low fat bolognas, extended with pea starch and fibre fractions was equivalent to the higher fat formulations (Pietrasik & Janz, 2010). It did however have an effect on the acceptability of the sausage for the 65+ age group. This age group positively (*P*≤0.05) correlated only the control sample for acceptability. The rest of the samples were not perceived as acceptable. This finding contradicts the work of Kälviäinen, Roininen, & Tuorila (2003), where it was found, that provided the ease of eating criterion is fulfilled, the elderly were more diverse in their texture likes than the young. Food neophobia is defined as the reluctance to try new or novel foods is often associated with the elderly (Otis, 1984). The elderly have established their patterns of eating over many years, and they dislike change, for security is achieved through the maintenance of rigidly led attitudes and rituals in which food acceptances play a large part (Horwath, 1991). Many studies suggest that a compensatory strategy by changing food texture is needed for the elderly (Ship, Duffy, Jones, & Langmore, 1996; & Forde & Delahunty, 2004). However, as this paper suggests, factors such as sensory changes due to aging and food neophobia should be taken into consideration when developing such compensatory strategies.

Table 5.4: *P* values of estimated regression coefficients (ANOVA values) for the relationships terms of sensory terms and sausage formulations (Table 2) as derived by Jack – knife uncertainty testing for sausages

The sign dictates whether the correlation is positively or negatively correlated significance of regression coefficients; ^{ns} = non-significant,

Age (yrs.)	Formulation	Hedonic Attributes				Intensity Attributes						
		Texture	Flavour	Acceptability	Colour	Spiciness	Coarseness	Toughness	Juiciness	Meat Flavour	Off Flavour	Saltiness
18-40	F30%, S2.5% RNa0%	0.0167 *	0.00031 ***	0.1692 ns	0.54574 ns	9.88E-10 ***	0.05095 *	0.31053 ns	0.04874 *	0.00033 ***	0.29445 ns	0.56148 ns
	F15%, S0% RNa1.13%	-0.4085 ns	-0.01965 *	-0.80823 ns	0.27775 ns	-0.00015 ***	-0.2979 ns	-0.43632 ns	-0.68597 *	0.01042 **	0.66283 ns	-0.88148 ns
	F15%, S1%, RNa0%	-0.10738 ns	-0.80909 ns	-0.12525 ns	0.15832 ns	-0.8234 ns	-0.25476 ns	-0.43632 ns	-0.68597 ns	-0.84273 ns	-0.268267 ns	-0.26322 ns
	F15%,S0%, RNa1%	-0.07344 ns	-0.5055 ns	-0.00247 **	0.00049 ***	-0.2195 ns	-0.2092 ns	-0.62441 ns	-0.31124 ns	-0.4256 ns	-0.33735 ns	-0.1647 ns
	F15%, S1.13%, RNa0%	-0.23777 ns	0.004783 ***	-0.691231 ns	0.11247 ns	-8.20E-07 ***	-0.12835 ns	-0.490719 ns	-0.02457 ns	-7.91E-08 ***	-0.58746 ns	-0.86039 ns
	F20%, S0% RNa1.13%	0.06321 ns	0.5727 ns	0.0043 **	-0.00215 **	0.33682 ns	0.12612 ns	0.5748 ns	0.3221 ns	0.54646 ns	0.26502 ns	0.24042 ns
	F20%, S1%, RNa0%	0.03564 *	0.59476 ns	0.000127 ***	-0.000422 ***	0.46736 ns	0.17677 ns	0.55785 ns	0.38108 ns	0.65041 ns	0.2890 ns	0.12079 ns
	F20%,S0%, RNa1%	0.0373 *	0.6397 ns	0.00106 ***	-0.00049 ***	0.65964 ns	0.15136 ns	0.54834 ns	0.42553 ns	0.78607 ns	0.315131 ns	0.13307 ns
	F20%, S1.13%, RNa0%	0.91758 ns	0.32336 ns	0.72461 ns	-0.45501 ns	0.21198 ns	0.97989 ns	0.9596 ns	0.26638 ns	0.2027 ns	0.8677 ns	0.57115 ns
41-65	F30%, S2.5% RNa0%	0.46924 ns	0.3727 ns	0.27368 ns	-0.1154 ns	0.12442 ns	0.56988 ns	0.78316 ns	0.28020 ns	0.21810 ns	0.51268 ns	0.40233 ns
	F15%, S0% RNa1.13%	0.07409 ns	0.4774 ns	0.00032 ***	-1.50E-06 ***	0.11627 ns	0.1817 ns	0.6158 ns	0.27242 ns	0.34681 ns	0.28409 ns	0.20514 ns
	F15%, S1%, RNa0%	0.82714 ns	0.20766 ns	0.93396 ns	-0.50119 ns	0.09873 ns	0.69694 ns	0.75291 ns	0.22950 ns	0.13573 ns	0.92144 ns	0.8155 ns
	F15%,S0%, RNa1%	0.0845 ns	0.4326 ns	0.01354 **	-0.00376 **	0.1102 ns	0.38228 ns	0.69447 ns	0.2073 ns	0.25845 ns	0.42820 ns	0.14659 ns
	F15%, S1.13%, RNa0%	0.19205 ns	0.41486 ns	0.029041 *	-0.00723 **	0.12818 ns	0.400296 ns	0.72459 ns	0.18573 ns	0.27238 ns	0.45165 ns	0.18635 ns
	F20%, S0% RNa1.13%	0.65612 ns	0.78773 ns	0.651712 ns	-0.687 ns	0.90138 ns	0.72724 ns	0.73161 ns	0.74769 ns	0.90535 ns	0.68328 ns	0.5991 ns
	F20%, S1%, RNa0%	0.61006 ns	0.5845 ns	0.71796 ns	-0.94009 ns	0.41124 ns	0.60515 ns	0.57832 ns	0.6636 ns	0.41803 ns	0.66281 ns	0.77234 ns
	F20%,S0%, RNa1%	0.68769 ns	0.22422 ns	0.35634 ns	-0.08664 ns	0.02144 *	0.90023 ns	0.97065 ns	0.13907 ns	0.0647 ns	0.71754 ns	0.31706 ns
	F20%, S1.13%, RNa0%	0.21089 ns	0.46139 ns	0.27773 ns	0.64706 ns	0.09182 ns	0.10698 ns	0.34268 ns	0.55881 ns	0.13807 ns	0.18466 ns	0.51969 ns
65+	F30%, S2.5% RNa0%	0.11575 ns	0.01972 **	0.39158 ns	-0.73198 ns	0.00036 ***	0.15225 ns	0.3265 ns	0.11512 ns	0.00829 **	0.38581 ns	0.66207 ns
	F15%, S0% RNa1.13%	-0.75669 ns	-0.33435 ns	-0.53192 ns	0.22299 ns	-0.22638 ns	-0.84924 ns	-0.91031 ns	-0.19676 ns	-0.25355 ns	-0.73385 ns	-0.53993 ns
	F15%, S1%, RNa0%	-0.50712 ns	-0.42847 ns	-0.36381 ns	0.18934 ns	-0.21697 ns	-0.53043 ns	-0.74651 ns	-0.29194 ns	-0.35097 ns	-0.51284 ns	-0.47958 ns
	F15%,S0%, RNa1%	-0.06648 ns	-0.00321 ***	-0.224 ns	0.70133 ns	-0.00043 ***	-0.0549 *	-0.32800 ns	-0.07817 ns	-0.00107 ***	-0.25629 ns	-0.5614 ns
	F15%, S1.13%, RNa0%	-0.02847 *	-0.04195 *	-0.09249 ns	0.75073 ns	0.00012 ***	-0.05055 *	-0.32174 ns	-0.17944 ns	0.00579 **	-0.20994 ns	-0.3239 ns
	F20%, S0% RNa1.13%	-0.05300 *	-0.00467 **	-0.13338 ns	0.92921 ns	-0.00021 ***	-0.04256 *	-0.3238 ns	-0.10749 ns	-0.00261 **	0.23665 ns	-0.48956 ns
	F20%, S1%, RNa0%	-0.83869 ns	-0.12804 ns	-0.86047 ns	0.35164 ns	-0.018 *	-0.70643 ns	-0.77475 ns	-0.07841 ns	-0.07681 ns	-0.9598 ns	-0.70876 ns
	F20%,S0%, RNa1%	-0.03684 *	-0.01942 *	-0.05451 *	0.821491 ns	-4.21E-05 ***	-0.00035 ***	- 0.27284 ns	-0.15234 ns	-6.16E-05 ***	-0.19077 ns	-0.44219 ns
	F20%, S1.13%, RNa0%	-0.10527 ns	- 0.002297 **	-0.2428 ns	0.7947 ns	-0.00058 ***	-0.03375 *	-0.30372 ns	-0.11755 ns	-0.00047 ***	-0.26457 ns	-0.58713 ns

* = ($P\leq0.05$), ** = ($P\leq0.01$), *** = ($P\leq0.001$). ºF: % of fat, S: % of NaCl, RNa: % of Reduced Na salt

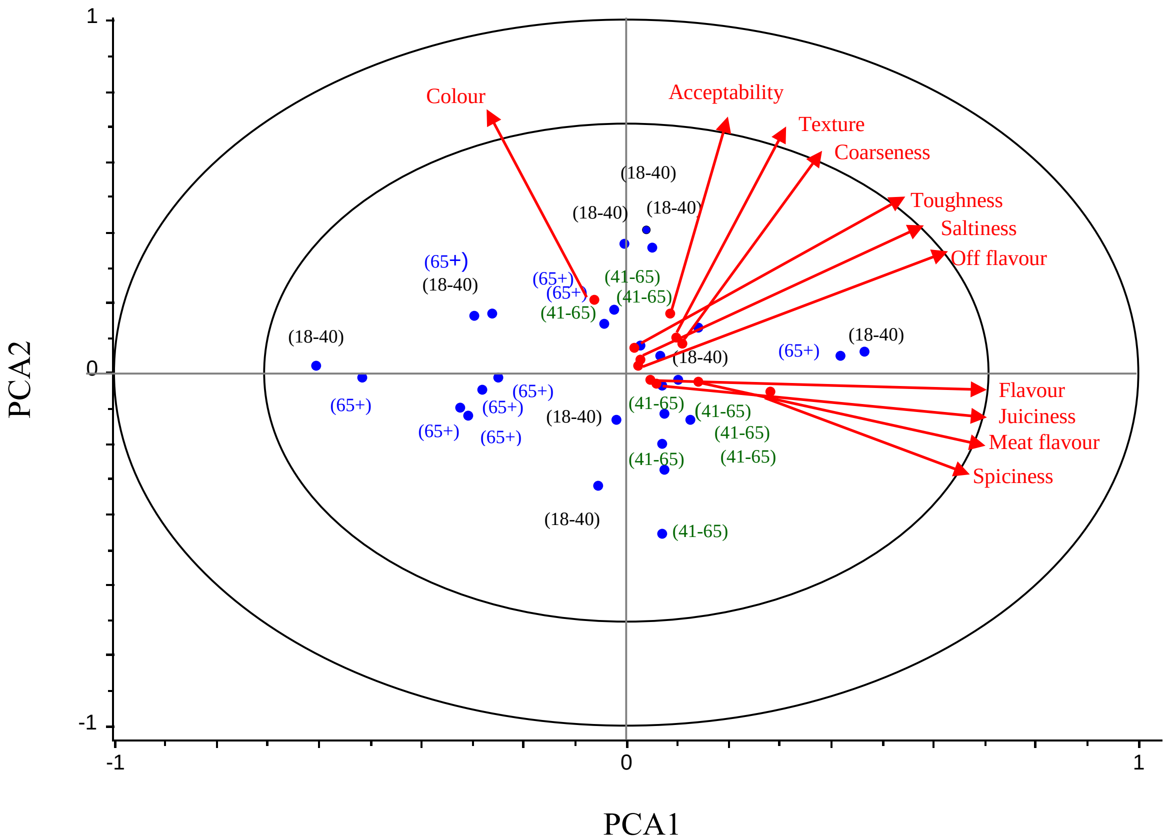

Figure 5.1. ANOVA – partial least squares regression (APLSR) correlation loading plot for each sensory descriptor and age category

This figure illustrates the loadings of the X and Y variables for the first two PCs.

Black: 18- 40 year olds, Green: 41-64 year olds Blue: 65+

3.2 Salt and the reduced sodium salt

From the data in Table 5.4, it is apparent that the 18-40 year old age group liked the control sample (F30,S2.5,RNa0) for spiciness ($P \leq 0.01$), flavour ($P \leq 0.001$), juiciness ($P \leq 0.05$) and meat flavour ($P \leq 0.001$). Salt is proven to be a flavour enhancer as suggested by Breslin, & Beauchamp (1995). This age group did not accept the higher level of reduced sodium salt (1.13%) as they negatively correlated sample (F15,S0,RNa1.13) for spiciness ($P \leq 0.001$), flavour ($P \leq 0.05$) and juiciness ($P \leq 0.05$). They did however positively correlate this sample for meat flavour ($P \leq 0.01$). Knaapila et al., (2016) found that regular users of a flavour rated its odour as more pleasant and familiar than did non-users. The 18-40 year age group favoured the flavour of the 0% reduced sodium salt sample. They associated sample (F15,S1.13,RNa0) with a positive flavour ($P \leq 0.001$). They did not perceive this sample as being spicy ($P \leq 0.001$) or having a meat flavour ($P \leq 0.001$).

There were no significant differences observed in the 41-65 age group in respect to the addition of the reduced sodium salt, with the exception of sample (F20,S0,RNa1) which was statistically positively associated with spiciness ($P \leq 0.05$). The 65+ age category associated the control sample containing 2.5% salt and the 0% reduced sodium salt sample with spiciness ($P \leq 0.001$), flavour ($P \leq 0.01$) and meat flavour ($P \leq 0.01$). The control sample was this age cohort's preferred sample. They did not associate any other samples with flavour. The findings of the current study are consistent with those of Laureati, Pagliarini, Calcinoni, & Bidoglio,. (2006a) who found that the elderly tend to confine food preference evolution to childhood, a life stage where people form their food preferences when (n=48) institutionalised the elderly aged between 57 and 98 were analysed. It was also found that simple-cooking, tradition and sensory aspects were the most important factors influencing the elderly's preference for traditional foods. (Horwath, 1991) stated that the eating habits of the elderly people are extremely difficult to change.

There are many studies examining the age related differences of varying NaCl levels in foods; Drewnowski, Henderson, Driscoll, & Rolls,. (1996) found that older subjects preferred less salty soups than did young adults. Jos Mojet, Heidema, & Christ-Hazelhof (2003) found that the perception of salt diminishes with age in varying solutions of NaCl dissolved in water. Murphy & Withee,. (1986) demonstrated a preference for high concentrations of NaCl in vegetable juices compared to the younger subjects examined. Younger subjects outperformed the elderly in an intensity discrimination of NaCl dissolved in tomato soup (Stevens, Cain, Demarque, & Ruthruff,. 1991).An increase preference for stronger flavours in the elderly subjects compared to younger age groups was found by Schiffman & Warwick (1993) whereby the elderly subjects in a retirement home using flavour enhanced foods and unenhanced foods was analysed. It was found that the subjects ate more of the enhanced foods and less of the unenhanced foods. Schiffman. (1998) also reported that the addition of MSG in foods improved food intake of hospital patients (n=43). The elderly age cohort (65+) did not like the flavour of the low salt sausages; (F15,S0,RNa1) ($P\leq0.001$), (F20,S0,RNa1.13) ($P\leq0.01$) & (F20,S0,RNa1) ($P\leq0.05$). This age cohort correlated the low salt sausages with a low intensity of saltiness on the intensity scale. Whereas, they associated the control sample intensity attributes such as spiciness and meat flavour. The elderly age cohort also rated the 0% salt samples as having an unpleasant texture. These results agree with work previously carried out by Tobin et al., (2013) who found lowering salt levels increase the coarse mouth feel of sausages to consumers. A number of studies have linked reducing salt with an undesired texture in a range of pork meat products such as frankfurters (Mcgough, Sato, Rankin, & Sindelar, 2012) and salami (Zanardi, Ghidini, Conter, & Ianieri, 2010).

3.3 Proximate Compositional Analysis

Proximate Compositional Analysis is presented in Table 5.5. Protein content differed within the samples. The control sample (F30,S2.5,RNa0) featured a statistically *(P*≤0.05) lower protein content than the other samples. This sample was the only sample that did not have pea extract included in its formulation. Thus, it can be concluded pea extract influences the protein content of sausages, when added at a level of 0.5%. All of the other samples protein levels did not differ statistically, except for sample (F20,S0,RNa1). Meat protein content was held constant in all of the samples, indicating that the slight increase in overall protein content in all the samples (except the control sample) was a function of proteins present in the pea extract. Similar results were found in the work of Pietrasik & Janz,. (2010) who found that pea and wheat flours raised the protein levels of low fat bologna sausages.

As expected the fat level in the control sample (F30,S2.5,RNa0) was statistically (*P*≤0.05) different to the rest of the samples. This sample contained 30% fat. The samples containing 15% fat were all categorised as being statistically the same. So too were the samples containing 20% fat. Salt levels varied statistically *(P*≤0.05) between the 2.5%, 1.13% 1% and the 0% salt formulations. Ash levels were also statistically *(P*≤0.05) higher in the control sample (F30,S2.5,RNa0). This was expected as the salt levels were also higher in this sample.

Table 5.5: Proximate compositional analysis values for cooked breakfast sausages of varying fat and salt content, whereby the percentage mean is presented ± the standard deviation

Sample	Protein (%)	Fat (%)	Moisture (%)	Ash (%)	Salt (%)	Carbohydrate (%)
F30,S2.5,RNa 0	$12.5 \pm 0.02^{a♦}$	28.5 ± 0.04^{c}	43.7 ± 0.24^{a}	3.3 ± 0.07^{e}	1.0 ± 0.00^{d}	12.1 ± 0.35^{f}
F15,S0,RNa1.13	19.7 ± 0.18^{b}	16.5 ± 0.03^{a}	52.2 ± 0.02^{d}	1.6 ± 0.02^{ab}	0.5 ± 0.00^{c}	9.9 ± 0.13^{de}
F15,S1.13,RNa0	19.9 ± 0.04^{b}	16.3 ± 0.20^{a}	51.6 ± 0.03^{d}	2.4 ± 0.07^{d}	0.1 ± 0.00^{a}	9.8 ± 0.08^{de}
F15,S0,RNa1	19.7 ± 0.02^{b}	16.3 ± 0.04^{a}	51.7 ± 0.02^{d}	1.5 ± 0.04^{a}	0.5 ± 0.00^{c}	10.8 ± 0.09^{ef}
F15,S1,RNa0	20.1 ± 0.04^{bc}	16.4 ± 0.19^{a}	51.9 ± 0.01^{d}	2.5 ± 0.04^{d}	0.4 ± 0.00^{b}	9.2 ± 0.14^{cd}
F20,S0,RNa1.13	19.9 ± 0.06^{b}	25.7 ± 0.01^{b}	45.5 ± 0.02^{bc}	2.4 ± 0.01^{d}	0.5 ± 0.00^{c}	6.6 ± 0.08^{a}
F20,S1.13, RNa1	19.7 ± 0.01^{b}	25.6 ± 0.04^{b}	44.9 ± 0.24^{b}	1.9 ± 0.01^{c}	0.1 ± 0.00^{a}	8.0 ± 0.27^{bc}
F20,S0,RNa1	20.5 ± 0.01^{c}	25.7 ± 0.06^{b}	45.3 ± 0.20^{bc}	1.8 ± 0.01^{bc}	0.5 ± 0.00^{c}	6.7 ± 0.25^{a}
F20, S1,RNa0	20.0 ± 0.02^{b}	25.6 ± 0.05^{b}	45.9 ± 0.15^{c}	1.6 ± 0.01^{ab}	0.4 ± 0.00^{b}	7.0 ± 0.05^{ab}

$^{♦abcde}$ Mean values (± SEM) in the same column that do not share a common superscript are significantly different, $P \leq 0.05$.

F: % of Fat, S: % of NaCl, RNa: % of Reduced Na salt

3.4 Physical analysis

The physical analysis of the cooked breakfast sausages are presented in Table 5.6. High values of cooking loss were noted in samples higher in fat. Significant differences were observed between samples in the three fat levels; 30%, 20% and 15%. Similar results have been noted in previous studies & (Hughes, Cofradesb, & Troy, 1997; Choi et al., 2009; & Tobin et al., 2013), whereby the higher the fat content, the greater the cooking loss in processed pork meat products. Cooking loss has being found to decrease with increasing amounts of starch (Pietrasik & Janz, 2010). Salt content is known to affect cooking loss. Ruusunen, Särkkä-Tirkkonen, & Puolanne. (2001) reported that cooked ham with added salt levels below 1.4% had higher cook losses compared to hams with salt levels greater than 1.7% The control sample featured the most salt (2.5%). This sample had statistically ($P \leq 0.05$) reduced cook loss compared to the other samples. Fat was found to have more of an influence on cook loss than salt in this study.

The colour of the sausages varied. Hunter Lab values indicated the L* value was statistically ($P \leq 0.05$) different in the control sample. Thus, the control featured a statistically lighter value than the other samples. The 15% fat samples containing the reduced sodium salt at 1.13% and 1% were not statistically different from each other in terms of colour. The L* values (lightness) of the final products were directly proportional to the fat content. The high fat products (30%) were lighter than the low-fat ones (15% & 20%). This result was predicted as the increase in the quantity of the white fat does contribute to the increase in L* value while a reduction in fat level generally favours the appearance of darker colourings (higher redness values and lower lightness values). When the fat content is reduced in processed meat products they become darker (Hughes, Cofrades, & Troy, 1997), (Morin, Temelli, & McMullen, 2004) & (Pietrasik, 1999). However, Ahmed, Miller, Lyon, Vaughters, & Reagan,. (1990) suggested that lightness values in fresh pork sausage are unaffected by simultaneous reduction in fat content and increase in water content because visual appearance is sustained. There were no significant differences observed between treatments for the a* and the b* Hunter values in this study. Texture profile analysis of the samples as measured by a texture analyser illustrates a range of correlations throughout the products. The lower fat sausages were found to be harder than the control sausage; samples (F15,S0,RNa1.13) (F15,S1.13,RNa0) and (F15,S0,RNa1) did not differ statistically ($P \leq 0.05$). Sample (F20,S0,RNa1) was also statistically the same. This may be due to the lack of salt in the sample. Samples (F20,S1.13,RNa1) and (F20,S1,RNa0) were also statistically the same ($P \leq 0.05$) for hardness. Many researchers have found low-fat pork products to be tougher than higher-fat ones (Bloukas, Paneras, & Fournitzis, 1997 & Barbut & Mittal, 1996).Varying levels of the reduced sodium salt concentrations had no difference on hardness.

The control sample was statistically ($P \leq 0.05$) different in resilience compared to the other samples. Samples (F15,S0,RNa1.13), (F15,S1.13,RNa0), (F20,S0,RNa1.13), (F20,S1.13,RNa1) and (F20,S1,RNa0) all had statistically ($P \leq 0.05$) similar results for resilience and protein. Fat may also contribute to resilience; Samples (F15,S0,RNa1.13), (F15,S1.13,RNa0) and (F15,S1,RNa0) also were statistically the same for resilience, protein and fat. A similar result was also noted in samples (F15,S0,RNa1) and (F15,S1,RNa0). In meat products, fat contributes to the flavour, texture, mouth feel and overall sensation of lubricity of the product. Fat reduction can therefore statistically affect the toughness of meat products (Barbut & Mittal, 1996).

Protein influences the springiness of meat products (Youssef & Barbut, 2011). This was also found in this study. The control sample had the lowest protein content (12.5 ± 0.02) and this sample was statistically ($P \leq 0.05$) different in terms of springiness. Samples (F15,S0,RNa1.13), (F20,S0,RNa1.13), (F20,S1.13,RNa1) and (F20,S1,RNa0) all were statistically (*P*≤0.05) the same in terms of springiness. They also were statistically (*P*≤0.05) the same in terms of protein and fat content. The same was observed for samples (F15,S1.13,RNa0), (F15,S0,RNa1) and (F15,S0,RNa1).

Fat has also been demonstrated to influence the springiness of sausages. The decreased springiness is proportional to the reduction in fat and these differences were significant (*P*≤0.05) between the batches. The control sample (F30,S2.5,RNa0) had a statistically (*P*≤0.05) higher fat content than the other samples. This in turn influenced the springiness of the sample. Samples (F15,S0,RNa1.13), (F15,S1.13,RNa0), (F15,S0,RNa1) and (F15,S1,RNa0) all were statistically (*P*≤0.05) the same for springiness and fat content. The same trend is observed in samples (F20,S0,RNa1.13) & (F20,S1.13,RNa1) where they were statistically the same for springiness and fat. Similar studies have demonstrated that fat influences springiness in sausages (Mendoza, García, Casas, & Selgas, 2001 & Keeton, 1994), however in contrast there are some studies to suggest that fat has no significant effect on springiness (Pietrasik, 1999 & Hughes et al., 1997). The increase in springiness may also be due to a reduction in the moisture content. Springiness is directly proportional to moisture contents in the samples. Springiness was found to increase when moisture was reduced in meat products Zhang, Liu, Zhu, & Wang (2018).

The highest cohesiveness values were associated with the control sample (F30,S2.5,RNa0). This sample featured the highest fat and salt content, both of which have been demonstrated to increase cohesiveness. Salt was statistically (*P*≤0.05) the same for samples (F15,S0,RNa1.13), (F15,S0,RNa1) and (F20,S0,RNa1). Cohesiveness was also statistically (*P*≤0.05) the same for these samples. Fat content also influenced cohesiveness as can be seen in sample (F20,S0,RNa1.13) and sample (F20,S1.13,RNa1). In this study cohesiveness was statistically (*P*≤0.05) higher in the 30% fat sample compared to the rest of the samples. Opposite results have been observed by (Pietrasik, 1999) whereby cohesiveness tended to decrease as fat content was increased from 15% to 25% in sausages. The 30% fat sample was the only sample not to have pea extract this may be a contributing factor to the differences in cohesiveness also.

Table 5.6: Physical analysis and cook loss values for breakfast sausages of varying fat and salt content whereby the percentage mean is presented ± the standard deviation

Sample	Colour			Cooking Loss (%)	Texture Profile Analysis			
	L	a	b		Springiness (mm)	Cohesiveness (N)	Hardness (N)	Resilience
F30,S2.5,RNa0	40.4 ± 0.03$^{g\blacklozenge}$	4.4 ± 0.04$^{ns\bullet}$	15.1 ± 0.12^{ns}	24.3 ± 0.04^{e}	0.8 ± 0.01^{a}	0.9 ± 0.37^{d}	13.1 ± 0.07^{a}	0.2 ± 0.00^{a}
F15,S0,RNa1.13	20.7 ± 0.07^{c}	3.0 ± 0.34^{ns}	12.9 ± 0.62^{ns}	16.4 ± 0.16^{b}	0.9 ± 0.01^{bcde}	0.7 ± 0.29^{bc}	23.4 ± 0.11^{d}	0.3 ± 0.00^{bcd}
F15,S1.13,RNa0	18.5 ± 0.06^{a}	3.8 ± 0.23^{ns}	15.1 ± 0.83^{ns}	16.7 ± 0.10^{bc}	1.0 ± 0.01^{de}	0.7 ± 0.29^{c}	23.6 ± 0.12^{d}	0.3 ± 0.00^{cde}
F15,S0,RNa1	21.4 ± 0.03^{c}	4.4 ± 0.04^{ns}	11.1 ± 0.12^{ns}	15.2 ± 0.12^{a}	1.0 ± 0.00^{e}	0.6 ± 0.24^{b}	23.1 ± 0.07^{d}	0.3 ± 0.0^{e}
F15,S1,RNa0	25.7 ± 0.03^{e}	2.7 ± 0.03^{ns}	13.1 ± 0.21^{ns}	15.2 ± 0.11^{a}	0.9 ± 0.02^{de}	0.6 ± 0.24^{b}	16.7 ± 0.13^{b}	0.3 ± 0.02^{ed}
F20,S0,RNa1.13	27.7 ± 0.09^{f}	4.5 ± 0.17^{ns}	14.8 ± 0.34^{ns}	20.5 ± 0.04^{d}	0.9 ± 0.01^{b}	0.4 ± 0.16^{a}	16.5 ± 0.13^{b}	0.3 ± 0.00^{bc}
F20,S1.13,RNa1	25.6 ± 0.12^{e}	4.1 ± 0.17^{ns}	13.9 ± 0.29^{ns}	19.7 ± 0.10^{d}	0.8 ± 0.01^{b}	0.5 ± 0.20^{a}	21.5 ± 0.13^{c}	0.3 ± 0.00^{bc}
F20,S0,RNa1	23.6 ± 0.12^{d}	2.9 ± 0.24^{ns}	11.7 ± 0.31^{ns}	17.5 ± 0.12^{c}	0.9 ± 0.01^{c}	0.6 ± 0.24^{b}	23.3 ± 0.15^{d}	0.3 ± 0.00^{b}
F20,S1,RNa0	19.5 ± 0.05^{b}	3.2 ± 0.22^{ns}	11.8 ± 0.24^{ns}	20.4 ± 0.16^{d}	0.9 ± 0.01^{bcd}	0.7 ± 0.29^{c}	21.2 ± 0.06^{c}	0.3 ± 0.00^{bc}

$\blacklozenge^{abcde}$ Mean values (± SEM) in the same column that do not share a common superscript are significantly different, $P \leq 0.05$.

^{ns} = non-significant

F: % of Fat, S: % of NaCl, RNa: % of Reduced Na salt

5. Conclusions

This research demonstrates various preferences for varying salt and fat formulations from three different age categories. It is interesting to note the differences among these age categories pertaining to their preferred fat and salt levels and the motives driving these preferences. Texture attributes influenced the younger age categories choice in sausage formulation, flavour and its associated attributes influenced the 41-64 year olds choice of sausage formulation, whereas visual aspects such as colour were the main driving force influencing the >65 yr. olds choice. These results can be explained by looking at the fat and salt preferences from the various age cohorts. Varying preferences among panellists for salt levels were observed. All age groups, with the exception of 65+ panellists accepted samples with salt levels below, or equal to, that of the FSAI 2017 salt targets. This study provides evidence that salt concentrations in sausages, and possibly other processed meats, may be reduced without having an impact on the sensory aspects perceived by consumers of certain age cohorts. This paper also provides evidence that age-related sensory differences in preferred fat concentrations exist; with 18-40 year olds preferring 20% fat sausages, 41-64 yr. olds preferring 15% fat sausages and the 65+ age group preferring 30% fat sausage. The 65+ age cohort demonstrated neophobic characteristics when novel sausage formulations were introduced. Reducing the levels of fat by adding pea extract caused varying results between all three age cohorts, especially with respect to product flavour and texture. Pea extract increased protein content. This is a valuable asset to food products tailor made for consumers, especially those with depleted muscle mass such as the elderly consumers. Pea extract may be used in further reformulations of food products to increase protein content. The elderly did not accept the reduced sodium salt as a salt replacer or the pea extract as a fat replacer, whereas the other two age cohorts did. The reduced sodium salt and the pea extract was widely accepted among the 41-64-year-old age group. This is important considering that this age group is our ‘future the elderly’.

This research suggests that those aged 41-64 are more accepting of novel formulations. This information can be used to develop tailor made food products with our ‘future’ the elderly consumer in mind. This research demonstrates different preferences and dislikes for various attributes presented by the reformulation of a traditional meat product based on the age of panellists consuming them. While selective targeted formulation of such products could be implemented, this study clearly shows that a considerable amount of research is needed to formulate processed meat products which will meet the sensory needs of the growing the elderly market, but which will allow the necessary reformulation to take place in order to improve the nutritional composition of such products for specific consumer groupings.

CHAPTER 6

Sensory analysis of MSG flavour-enhanced traditional breakfast sausages: A consumer age profile

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Abstract

Monosodium Glutamate (MSG) is commonly used in processed foods and it is hypothesised to enhance saltiness perception. In this study, MSG usage was investigated as a model salt reduction strategy and its sensory effects were examined using breakfast sausages as a product model. The sample size of the three sensory age cohorts employed in this study were; 18-40 yrs. (years) (n=81), 41-64 yrs. (n=84) and 65-85 yrs. (n=63). MSG was incorporated into sausages at levels of 0.1, 0.2 and 0.3%. Its interactive impact on sensory properties in sausages containing NaCl and a reduced salt (reduced sodium sea salt) ingredient were examined. This study also examined the usage of MSG at levels of 0.1, 0.2 and 0.3% in the absence of NaCl or reduced sodium sea salt in sausage formulations.

By adding 0.2% MSG to sausage formulations, perception of meat flavour increased in those aged under 20 yr. old. The 21-40 age cohort's sensory perception was influenced by a 0.1% change in MSG. The 41-64 age cohort displayed decreased perception for NaCl, compared to the younger age cohorts. The 66-75 yr. olds did not like samples that contained 0.3% MSG, whereas 76-80 yr. olds did. The 61-65 and 66-75 age cohorts were more influenced by texture than younger age cohorts.

The effects that MSG has on intensity and hedonic attributes are very specific to consumer groupings based on age.

Key Words: Gustation, Olfaction, Flavour Enhancement, The elderly People, Flavours, MSG

6.1 Introduction

Age-related changes in food consumption are often manifested in a decreased energy intake in older persons, which can lead to a decrease in body fat and body weight. Consequently, older people are more susceptible to health-related problems, such as decline in functional status, impaired muscle function, decreased bone mass, micronutrient deficiencies, reduced cognitive functions, increased hospital admissions and premature death (Ahmed & Haboubi, 2010). Malnutrition is often not recognised, but can be a major threat to the independence and quality of life in older adults (Volkert, Saeglitz, Gueldenzoph, Sieber, & Stehle, 2010). A poor appetite in the elderly may be explained by the physiological processes of decreased physical activity and the altered regulation of food intake leading to decreased food intake (Morley, 1997). A poor appetite is thought to be linked with the impairment of chemosensory abilities, and the ability to perceive an odour or a taste due to aging (Schiffman, 1993; Mojet, Christ-Hazelhof & Heidema, 2001).

Our perception of flavour incorporates both our sense of taste (gustatory) and sense of smell (olfaction). Loss in the sense of taste are more commonly perceived in those over the age of 60 (Hoffman, Cruickshanks & Davis, 2009). For the taste qualities; salt (NaCl), sour (citric acid) and sweet (sucrose) detection thresholds among seniors are increased 2-fold, 1.5-fold, and 1.4–fold respectively, compared to young adults. Many studies have demonstrated an increase in various food uptake among the elderly consumers when flavour profile was enhanced (Griep, Mets & Massart, 2000; & Koskinen, et al., 2003). Dietary variety has proven to increase food consumption in older adults in the UK (Hollis & Henry, 2007). However, it has been proven that older patients have a dislike for meat (Gustafsson, Ekblad, & Sidenvall, 2005; & Sidenvall, 2005). Due to impairments in the gustatory and the olfactory systems, an impaired sensory perception of foods may promote the consumption of salt to compensate for the lack of flavour from food (Duffy, Backstrand & Ferris, 1995).

High salt intake causes a rise in blood pressure (BP), (He, Li & Macgregor, 2013), thereby increasing the risk of cardiovascular disease (CVD), strokes, heart attacks and heart failure (Tuomilehto et al., 2001) and renal disease (Swift, Markandu, Sagnella, He & MacGregor, 2005). Many studies have examined the effect of salt reduction in several meat products (Fellendorf, O'Sullivan & Kerry, 2016; Fougy et al., 2016; Fellendorf, O'Sullivan, & Kerry, 2015; Tobin, O'Sullivan, Hamill & Kerry, 2012a; & Tobin, O'Sullivan, Hamill & Kerry, 2012b; & Ruusunen & Puolanne, 2005). Salt can be reduced successfully; however, the sensory effects may be different for various age cohorts. In a previous study carried out by the authors examining salt reduction in breakfast sausages on various age cohorts, age-related sensory differences were noted when salt was reduced in breakfast sausages; The18-40 age cohort preferred high salt samples containing 2.5% NaCl. The 41-64 age cohort had no salt preference, while those aged 65+ preferred high salt sausage formulations (2.5% NaCl). There is evidence to suggest that umami flavour can increase salt perception (Kremer, Mojet, & Shimojo, 2009). The use of umami taste to aid salt reduction is promoted by the food industry (CTAC, 2009). Monosodium glutamate is a food additive known to be a flavour enhancer. It enhances the complex flavours of meat, poultry, vegetables and seafood. It is often described as the meaty/broth like taste of umami. The most pronounced age-related changes have been observed for salty and umami tastes (Mojet, 2003; & Mojet et al., 2001). There are many conflicting studies examining the effect of MSG taste enhanced food on liking of the elderly consumption. When MSG and flavourings were added to nursing home resident's (n=50) food, (mean age=82 yrs. old) the satisfaction ratings increased (Schiffman, 1998). Other studies have shown no preferences between senior and young subjects for concentrations of salty, bitter or umami tastants (Jos Mojet, Christ-Hazelhof, & Heidema, 2005 & Mojet et al., 2005). From extensive research of the scientific literature to date, none have been conducted into how the effects of a model flavour enhancing ingredient, such as MSG, is perceived by various age cohorts when added to salt-reduced breakfast sausages.

This study set about to determine the effect of small incremental changes of a model flavour enhancer like MSG, on the palatability of salt-reduced and salt-replaced traditional sausages. It examined these changes from a sensory (intensity and hedonic) perspective and it established an age profile at which these increments were liked/disliked among consumers, ultimately determining if MSG is a viable salt replacer.

6.2 Materials and Methods

6.2.1 Reagents and chemicals

Sulphuric acid, hydrogen peroxide, boric acid, hydrochloric acid, sodium hydroxide and silver nitrate were supplied by Sigma-Aldrich Ireland Ltd., Vale Road, Arklow, Wicklow, Ireland.

6.2.2 Sausage Preparation

Fresh boneless pork and pork back fat was purchased from local processors (Ballyburden Meats Ltd, Ballincollig, Cork, Ireland). The meat and fat were cut, weighed, vacuum packaged and stored in the freezer (-18°C). Prior to use, meat and fat were thawed slightly at 4°C before being minced through a 10mm plate (TALSABELL S. A., Spain).

All ingredients were weighed according to formulations presented in Table 6.1. Fat was replaced by pea extract in sausage samples. From a previous study carried out by the same authors, pea extract proved to be a successful fat replacer. Pea extract level was constant with the exception of the control which did not contain pea extract, but instead contained a higher amount of fat (30%). When used in sausage formulations, reduced sodium sea salt and NaCl were added at a level of 1%. MSG was added in increments of 0.1, 0.2 & 0.3%. The seasoning used contained no NaCl. The reduced sodium sea salt, pea extract and MSG were purchased from All in All Ingredients Ltd., Unit 33 Lavery Avenue, Parkwest, Dublin 12, Ireland.

The specific composition of the ingredient reduced sodium sea salt is presented in Table 6.2. Pork, seasoning, salt, pea extract, reduced sodium sea salt and a third of the required water were fed into a bowl chopper and mixed at high speed for 45sec. The required fat was then added to the bowl chopper and the mix was chopped for a further 45sec. at high speed. The remaining water was added for 30sec. at high speed. Finally, pin-head rusk was added and chopped for a further 30sec. at low speed. The sausage mix was then placed into a sausage filler and fed or stuffed into collagen-based casings. Sausages were then sealed in vacuum pack bags and refrigerated overnight (4°C). Ten-treatment batches were manufactured on three separate occasions.

6.2.3 Cooking

Oven-cooking was chosen as the method to cook the sausages. Each sausage sample was wrapped in tin foil, labelled and dry cooked at 150°C in a Zanussi convection oven (C. Batassi, Conegliano, Italy) for 20min to an internal temperature of 73°C, as measured by a temperature probe (Testo 110, Lenzkirch. Germany).

Table 6.1: Sausage Formulations

%	C	RNa1,N0,0.1	RNa1,N0,0.2	RNa1,N0,0.3	RNa0,N1,0.1	RNa0,N1,0.2	RNa0,N1,0.3	RNa0,N0,0.1	RNa0,N0,0.2	RNa0,N0,0.3
MSG	0	0.1	0.2	0.3	0.1	0.2	0.3	0.1	0.2	0.3
NaCl	2.5	0	0	0	1	1	1	0	0	0
RNa	0	1	1	1	0	0	0	0	0	0
Fat	30	15	15	15	15	15	15	15	15	15
Pea	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pork	35	35	35	35	35	35	35	35	35	35
Rusk	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Seasoning	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Water	17.5	33.4	33.3	33.2	33.4	33.3	33.2	34.4	34.3	34.2

C = Control, RNa = Reduced Sodium Salt, N = NaCl, MSG = Monosodium Glutamate

Table 6.2: Reduced Sodium Salt Composition

Ingredient	**Composition g/100g**
Sodium	22.0 ± 0.6
Chloride	34.0 ± 0.9
Sulphate	23.0 ± 0.7
Potassium	9.0 ± 0.3
Magnesium	2.0 ± 0.1
Trace Elements	0.3 ± 0.0
Free and bound moisture	10.0 ± 1.5

Ingredient levels in the 45% reduced salt blend

6.2.2 Proximate Compositional Analysis

6.2.2.1 Protein Content

The Kjeldahl method was used to determine protein content in breakfast sausage samples (Suhre, Corrao & Glover, 1982), and percentage protein was calculated using a nitrogen conversion factor of 6.25. This method was in accordance with the work outlined by Tobin et al (2013). The results recorded represent the average of six measurements (three independent batches x two samples x one reading).

6.2.2.2 Ash Content

Ash content of sausages was measured using a muffle furnace (Nabertherm GmbH, Lilienthal, Germany). The muffle furnace was preheated to 525°C. A 5g blended sample was weighted into a porcelain dish and placed in the muffle furnace for 6 hr, until the colour of the samples turned white. The samples were placed in a desiccator to cool. The dishes were weighted and ash content calculated. The results recorded represent the average of six measurements (three independent batches x two samples x one reading).

6.2.2.3 Moisture and Fat Content

Sausage samples (200g) for each sausage formulation was homogenised using a Büchi Mixer B-400 (Büchi Labortechnik AG, Meierseggstrasse 40, Postfach, CH-9230 Flawil 1, Switzerland). Each sample was transferred into a moisture proof bag to minimise moisture loss, Moisture content was then determined in samples using the CEM SMART system and fat was determined using the SMART Trac system. The results recorded represent the average of six measurements (three independent batches x two samples x one reading).

6.2.2.4 Carbohydrates

Total carbohydrates were determined by difference. Subtracting the addition weight of protein, fat, water and ash in grams from 100g, expressed as a percentage, resulted in what was determined to be carbohydrate level. The results recorded represent the average of six measurements (three independent batches x two samples x one reading).

6.2.2.5 MSG

MSG levels in the samples were determined using HPLC (high performance liquid chromatography) equipped with UV detection according to the methods of Mustafa, Saleem, Hameed, & Author (2015). The results recorded represent the average of six measurements (three independent batches x two samples x one reading).

6.2.2.6 Salt

Salt concentrations were measured in accordance with that reported by Fox (1963). The samples were homogenised thoroughly. A 2g of sample of sausage meat was added to 100ml of dilute nitric acid solution (1.5ml conc. Nitric acid/L). Samples were placed in a water bath at 60°C for 15min. The sample was then titrated with 0.1M $AgNO_3$ to +255mV using a potentiometer equipped with silver and reference electrodes. During titration, a magnetic stirrer was used to assist solution mixing. A bank titration was also carried out. By means of the ratio to chloride, sodium chloride concentrations were calculated for each sample set. The results recorded represent the average of six measurements (three independent batches x two samples x one reading).

6.2.3 Sensory Analysis

6.2.3.1 Recruitment

Panellists of varying age cohorts were recruited for this study. Panellists were chosen in compliance with the following criteria; community dwelling, healthy, not on a prescribed diet, did not have a food allergy, did not have any difficulties swallowing, and were regular consumers of breakfast sausages. All subjects were recruited from University College Cork and from active retirement groups based around the Cork region. The assessor cohorts were derived from various socio-economic backgrounds and were gender balanced.

6.2.3.2 Sensory Evaluation

Sensory analysis was carried out on untrained assessors (n=228). The ages ranged from 18-85 yrs. old. The sample size of the three age cohorts were 18-40 yrs. (n=81), 41-64 yrs. (n=84) and 65-85 yrs. (n=63). Each panellist rated the sensory qualities of samples in triplicate. The following hedonic attributes were assessed: Tenderness, flavour, firmness, texture and acceptability. The following intensity attributes were assessed: saltiness, spiciness, meat flavour, metallic flavour and off-flavour are presented in Table 6.3. The descriptors used in the study were chosen after consulting a trained sausage panel. All samples were presented to panelists randomised on white polystyrene plates. Panellists were asked to rinse their mouths with water in-between each sample assessment in accordance with the methods of Tobin et al. (2012a).

6.2.4 Physical Analysis

6.2.4.1 Texture Analysis

After cooking, all sausage samples were cooled to room temperature (20°C) to determine textural properties. Texture was measured using a texture profile analyser; (Texture Analyser 16 TA-XT2I Stable Micro Systems, Surrey, UK) following AMSA, (1995) procedures. Cylindrical slices (10mm x 10mm) were taken from each sausage. Each slice underwent a two-cycle compression test using a 25kg load cell. Samples were compressed to 40% of their original height with a 35mm diameter probe (SMSP/35 compression plate) and a cross head speed of 1.5mm/s. Textural factors were measured using descriptors highlighted by Bourne (1978).

They included hardness (N): maximum force required for the initial compression of the sample, springiness (mm): the samples' ability to recover its original shape after the initial compression and the deforming force are removed, adhesiveness (N x mm): area under the abscissa post initial compression, cohesiveness (dimensionless): extent to which the sample could be deformed prior to rupture, measured by the areas under the compression portion instead of using the total area under positive force, chewiness (N x mm): the required work to masticate the sample, measured as the product of hardness times cohesiveness times springiness (mm) and resilience (dimensionless): the ratio between the negative force input to positive force input during the first compression. The results recorded represent the average of six measurements (three independent batches x two samples x one reading).

6.2.4.2 Colour

Surface colour was measured on the cooked sausages. The sausages were brought to room temperature (20°C) before analysis. The sausages were cut down the middle before being analysed in in the colourimeter (Minolta Camera Co. Ltd., Osaka, Japan). Lightness (L*), redness (a* ± red-green) and yellowness (b* ± yellow-blue) were measured. The colometer features an 11mm – diameter aperture and D65 illuminant, calibrated by the CIE Lab colour space system using a white tile (C: y = 93.6, x = 0.3130, y = 0.3193). A CIE 19312º standard observer was used. A Minolta calibration plate was used to calibrate the analysis. Colour was measured by following the guidelines for colour measurements from AMSA, (2012). Duplicate colour measurements were recorded on two samples from each experimental batch.

6.2.4.3 Cooking Loss

Sausage sample weights were recorded both before and after cooking. Differences in weights were recorded. Each sample was wrapped in aluminium foil before cooking. Before weighing, each sample was blotted with a paper towel to remove excess moisture. Cooking loss was determined as the difference between cooked and raw weights expressed as a percentage of the raw weight. Results recorded represent the average of six measurements (three independent batches x two samples x one reading).

6.2.5 Statistical Analysis

A mixed model ANOVA was conducted in SPSS. The following interactions were measured: Treatment, age, age*treatment, session, batch and panellist. Fixed effects included treatments and panellist's ages. Product batches, panellists and sessions were included as random effects. All datasets were subjected to descriptive analysis and tests for normality (Shapiro-Wilk test), Independence and Equality of Variances (Levene's test) were performed. The assumptions of the relevant statistical tests were satisfied in all cases. Tukey's HSD post-hoc test was used to determine significant differences within groups. Results can be viewed in Table 4. Data obtained from sausage sensory trials were analysed using ANOVA – Partial Least Squares Regression (APLSR) to process the mean data accumulated from the test subjects. Data was processed using Unscrambler software version 10.3. (CAMO ASA, Trondheim, Norway). The X-matrix was designed as different age categories and sausage samples. The Y – matrix involved the hedonic and intensity variables of the design. Fixed effects were age cohorts, while random effects were sensory results and sausage samples. Principal components i.e. PC1 versus PC2 are presented (Figs. 6.1, 6.2, 6.3 & 6.4). Regression coefficients were analysed by Jack-knifing (Tables 6.7, 6.8, 6.9 & 6.10) to derive significant indicators for relationships determined in quantitative APLSR plots, which are based on cross-validation and stability plots.

Proximate (Table 6.5) and physiochemical (Table 6.6) data are presented as mean values ± standard error of the mean (SEM). One-way ANOVA was used to examine data from proximate and physiochemical analysis. Tukey's post-hoc test was used to adjust for multiple comparisons between treatment means. All statistical analysis was carried out using the SPSS 11.0 software package for Windows (SPSS, Chicago, IL, USA).

6.3 Results and discussion

6.3.1 Proximal Composition

Proximal compositional results are presented in Table 6.5. The NaCl levels ranged from 0.7-3.7%. Percentage NaCl was significantly higher in the control sample as expected (3.7 ± 0.04). Sausage samples in which 1.0% NaCl was added to the formulations did not differ when statistical analysis on NaCl was carried out, as expected. Higher values for NaCl were obtained from proximal compositional testing than the initial formulation. This may be attributed to some salt being present in the reduced sodium sea salt seasoning (Table 6.2).

The control sample had similar values of MSG to other samples. This finding was unexpected, as no MSG was added to the control sample. Contrary to expectations, samples containing reduced sodium sea salt 1.0%, NaCl 0.0%, MSG 0.1%, reduced sodium sea salt 1.0%, NaCl 0.0%, MSG 0.2%, reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.1% and reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.2% were statistically the same as the control sample. The MSG determination method outlined in this study measured glutamates. According to Jinap & Hajeb (2010), animal proteins may contain 11-22% glutamate. The high amount of MSG recorded in the control sample may be attributed to the fact that animal protein naturally contains glutamates.

Table 6.5: Proximal compositional analysis values for breakfast sausages

Sample	Ash (%)	Carbohydrates (%)	Fat (%)	Moisture (%)	MSG (%)	NaCl (%)	Protein (%)
C	3.3 ± 0.07^{g}	15.1 ± 0.35^{a}	25.5 ± 0.04^{e}	43.7 ± 0.24^{a}	0.5 ± 0.00^{a}	3.7 ± 0.04^{f}	12.5 ± 0.02^{a}
RNa1,N0,0.1	0.4 ± 0.04^{ab}	18.0 ± 0.03^{b}	10.4 ± 0.03^{b}	51.6 ± 0.09^{e}	0.6 ± 0.03^{ab}	1.8 ± 0.02^{cd}	19.7 ± 0.01^{bc}
RNa1,N0,0.2	0.9 ± 0.01^{cd}	17.1 ± 0.05^{b}	9.7 ± 0.01^{a}	51.7 ± 0.04^{ef}	0.6 ± 0.03^{bc}	0.7 ± 0.04^{a}	20.5 ± 0.02^{d}
RNa1,N0,0.3	0.5 ± 0.04^{bc}	17.3 ± 0.07^{b}	10.5 ± 0.02^{b}	51.7 ± 0.04^{ef}	0.7 ± 0.01^{bc}	1.2 ± 0.20^{abc}	20.0 ± 0.02^{bc}
RNa0,N1,0.1	1.1 ± 0.23^{de}	23.2 ± 0.04^{d}	11.4 ± 0.02^{d}	44.6 ± 0.04^{b}	0.7 ± 0.01^{cd}	2.0 ± 0.00^{de}	19.7 ± 0.02^{bc}
RNa0,N1,0.2	0.8 ± 0.03^{cd}	17.5 ± 0.07^{b}	9.9 ± 0.02^{a}	51.8 ± 0.06^{ef}	0.9 ± 0.02^{e}	2.4 ± 0.00^{e}	20.1 ± 0.04^{cd}
RNa0,N1,0.3	1.3 ± 0.04^{def}	17.5 ± 0.04^{b}	10.9 ± 0.01^{c}	50.5 ± 0.06^{df}	0.8 ± 0.01^{de}	2.4 ± 0.01^{e}	19.9 ± 0.06^{bc}
RNa0,N0,0.1	1.4 ± 0.09^{def}	25.3 ± 0.30^{e}	10.5 ± 0.04^{b}	43.3 ± 0.24^{af}	0.6 ± 0.02^{abc}	1.0 ± 0.00^{ab}	19.5 ± 0.02^{b}
RNa0,N0,0.2	1.5 ± 0.06^{f}	15.4 ± 0.28^{a}	10.7 ± 0.02^{c}	52.6 ± 0.12^{f}	0.5 ± 0.02^{ab}	1.5 ± 0.12^{bcd}	19.7 ± 0.18^{bc}
RNa0,N0,0.3	0.2 ± 0.05^{a}	20.8 ± 0.12^{c}	11.5 ± 0.02^{d}	47.7 ± 0.07^{c}	0.7 ± 0.03^{bc}	1.8 ± 0.12^{ac}	19.9 ± 0.04^{bc}

^{abc}Mean values (±SEM) in the same column bearing different superscripts are significantly different, $P \leq 0.05$ RNa = Reduced Sodium Salt, N = NaCl

6.3.2 Physical Composition

Physiochemical results obtained from analysis are shown in Table 6.6. One important attribute of sausages, and indeed other meat products, is their ability to hold moisture in the product both before and after cooking. Cooking loss was used to measure the amount of juices lost during cooking and cooking losses varied among samples. Cooking loss values ranged from 9.0-24.3%. The greatest cook loss was associated with the control sample (24.3±0.04). This may be due to the high fat content of this sample. Fat is known to affect the cooking loss of meat. The results presented in this study disagree with those presented by Chun et al. (2014) who found that the replacement of NaCl with MSG resulted in higher cook losses from pork patties.

Colour results varied within product formulation treatments. The reduction of NaCl provided significant differences in the L* values. The darkest sausage samples were those containing 1.0% NaCl. The control sausage sample contained 2.5% NaCl and the resulting products had a lighter colour. NaCl usage has been found to increase lightness in products (Boyle, Addis, & Epley, 1994). There were no minus results associated with the a* lab value of the MSG sausage samples in this trial, indicating that there were no green colours or hues associated with samples. They were all positive values indicating a strong pink/magenta colour. There were also no negative values associated with b lab values indicating that the samples was more yellow in colour than blue.

Texture measured by the texture profile analyser varied among the various sausage formulations. Springiness is the products ability to return to its original dimensions after a deformation. Hardness was calculated as the peak force of the first compression. The control sample was the softest sample. This may be due to its higher fat and salt contents. This result was expected as lower fat sausages have been reported to be tougher than higher fat sausages (Cengiz & Gokoglu, 2007).

Chewiness was explained as the ability of the product to withstand a second deformation relative to its first deformation. The control sample was the least ‘chewy’ sample. This sample varied significantly from the other samples. This may be due to the higher fat content. Many studies have demonstrated a higher level of chewiness in low fat sausages (Olivares, Navarro, Salvador, & Flores, 2010 & Tobin et al., 2013). This information may be useful when formulating sausages for the elderly consumers with limited chewing ability. Less resilience was associated with the control sample. This sample was best able to return to its original height. A similar result was observed in previous work carried out by the authors whereby the sausage sample containing 30% fat (control) was significantly less resilient than the reduced fat samples of 15% and 20%.

Table 6.6: Physiochemical compositional analysis values for breakfast sausages

Sample	Cook loss (%)	L	a	B	Springiness (mm)	Hardness (N)	Chewiness (N)	Resilience *
C	24.3 ± 0.04^{h}	40.4 ± 0.03^{c}	4.4 ± 0.04^{a}	15.1 ± 0.12^{a}	0.8 ± 0.01^{ab}	13.1 ± 0.07^{a}	9.6 ± 0.98^{a}	0.2 ± 0.02^{a}
RNa1,N0,0.1	13.0 ± 0.00^{f}	44.9 ± 0.14^{d}	6.0 ± 0.02^{e}	23.3 ± 0.03^{f}	0.8 ± 0.03^{ab}	44.9 ± 0.58^{cd}	17.3 ± 0.38^{cd}	0.3 ± 0.00^{bc}
RNa1,N0,0.2	9.0 ± 0.00^{a}	45.3 ± 0.07^{d}	7.0 ± 0.02^{f}	24.7 ± 0.01^{g}	0.7 ± 0.04^{a}	28.9 ± 1.89^{b}	10.6 ± 1.29^{ab}	0.3 ± 0.01^{b}
RNa1,N0,0.3	14.0 ± 0.00^{g}	48.6 ± 0.01^{f}	5.8 ± 0.01^{d}	23.0 ± 0.01^{f}	0.7 ± 0.01^{a}	42.5 ± 0.94^{c}	16.2 ± 0.55^{cd}	0.3 ± 0.00^{bc}
RNa0,N1,0.1	9.7 ± 0.04^{b}	38.7± 0.19^{b}	5.5 ± 0.01^{c}	18.7 ± 0.01^{c}	0.7 ± 0.02^{a}	39.9 ± 2.00^{c}	15.4 ± 0.49^{bc}	0.3 ± 0.01^{bc}
RNa0,N1,0.2	10.4 ± 0.02^{d}	39.3 ± 0.01^{bc}	7.0 ± 0.01^{f}	19.0 ± 0.01^{c}	0.9 ± 0.02^{b}	55.6 ± 1.96^{e}	26.1 ± 1.23^{f}	0.3 ± 0.00^{bc}
RNa0,N1,0.3	10.1 ± 0.04^{c}	32.2 ± 0.26^{a}	6.2 ± 0.01^{e}	18.2 ± 0.01^{b}	0.8 ± 0.01^{ab}	54.6 ± 0.64^{e}	25.7 ± 0.44^{f}	0.3 ± 0.00^{c}
RNa0,N0,0.1	10.4 ± 0.06^{d}	46.5 ± 0.06^{e}	5.0 ± 0.00^{b}	21.8 ± 0.00^{d}	0.8 ± 0.01^{ab}	48.7 ± 1.47^{cde}	21.1 ± 0.33^{def}	0.3 ± 0.02^{bc}
RNa0,N0,0.2	11.3 ± 0.05^{e}	47.0 ± 0.01^{e}	5.7 ± 0.01^{d}	22.4 ± 0.02^{e}	0.8 ± 0.01^{ab}	42.6 ± 0.82^{c}	19.6 ± 0.30^{cde}	0.3 ± 0.01^{bc}
RNa0,N0,0.3	10.4 ± 0.04^{d}	48.3 ± 0.04^{f}	4.9 ± 0.01^{b}	21.8 ± 0.15^{d}	0.8 ± 0.02^{ab}	53.6 ± 0.89^{de}	23.9 ± 0.69^{ef}	0.3 ± 0.01^{c}

^{abc} Mean values (± SEM) in the same column bearing different superscripts are significantly different, $P \leq 0.05$

F: % of Fat, S: % of NaCl, RNa: % of Reduced Na salt, * (n/a) resilience measurement is dimensionless

6.3.3 Sensory

From Table 6.4 it can be seen that session, batch, age interaction significantly affected all of the hedonic and the intensity sensory descriptors. The results observed from the sensory trial of the MSG sausages are shown in Tables 6.7, 6.8, 6.9 & 6.10.

6.3.3.1 Twenty and under-age category

The twenty and under age category disliked the flavour of the samples containing: reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.1% ($P \leq 0.05$), reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.3% ($P \leq 0.01$) and reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.2% ($P \leq 0.01$), as can be seen from Table 6.7. This age cohort did not significantly accept any of the sausage samples. This result is confirmed in Fig 6.1. The hedonic descriptor of acceptability is located on the bottom right quadrant. There is no twenty or under age cohort located in this quadrant. The under 20 age cohort did not perceive any significant intensity attributes with the control sample. However, by adding 0.2% MSG to the sausage formulation, the perception of meat flavour increased. This age cohort associated the sample containing only reduced sodium sea salt and 0.3% MSG with a meat flavour ($P \leq 0.001$) this sample was not associated with metallic flavour ($P \leq 0.001$). As meat flavour increased, metallic flavour decreased. Many studies have shown that as meat ages, the metallic flavour perception increases (Yancey et al., 2006 & Calkins, 2006). As rancid flavours develop, a subsequent loss in desirable flavour notes occurs (Campo et al., 2006).

The addition of MSG at different concentrations induced varying intensity associations among this age cohort in the samples containing 1.0% NaCl. The sample containing 1.0% NaCl and 0.1% MSG (reduced sodium sea salt 0.0 %, NaCl 1.0 %, MSG 0.1 %) was not associated with spiciness or off flavour ($P \leq 0.05$) by this age cohort, whereas, the sample containing 1.0% NaCl and 0.2% MSG (reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.2%) was associated with meat flavour (*P≤0.01*). The sample containing reduced sodium sea salt 0%, NaCl 1.0%, MSG 0.3% was not associated with spiciness (*P≤0.01*). Those in the twenty and under-age category perceived saltiness as being stronger for samples that contained MSG rather than NaCl. Samples which contained the following formulations; reduced sodium sea salt 1.0%, NaCl 0.0%, MSG 0.1%, reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.2% and reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.3% were all perceived as salty (*P≤0.01*), (*P≤0.05*) & (*P≤0.01*), respectively. It is interesting to note that two of these samples did not contain any of the salt ingredients; NaCl or reduced sodium sea salt. Thus, the perception of saltiness was increased with the addition of MSG at levels 0.1-0.3% for those aged twenty and under. This demonstrates the ability of MSG to enhance flavours and to increase saltiness perception. Similar findings were observed in a study examining the effect of NaCl and MSG on meat products (Chun et al., 2014). The replacement of NaCl with MSG resulted in an enhanced salty flavour, thereby increasing the acceptability of the meat product. These authors concluded that to be effective in inducing a salty flavour, MSG should be used in meat products rather than in an MSG/NaCl complex. In this current study, sausages were manufactured by adding MSG to the meat product. This may be the reason for the increased salty perception of sausages containing no added NaCl. The palatability of MSG depends on the amount of NaCl present in the food.

6.3.3.2 Twenty-one to forty age categories

The 21-40 age cohort liked sausage samples containing reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.1% for flavour (*P≤0.01*), whereas they did not like the flavour associated with the same sample containing 0.1% more MSG (reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.2 %) (*P≤0.05*). This age cohort's sensory perception was influenced by a 0.1% change in added MSG. The 21-40 age cohort associated the control sample (reduced sodium sea salt 1.0%, NaCl 0.0 %, MSG 0.1 %) and the sample containing (reduced sodium sea salt 1.0 % NaCl 0.0%, MSG 0.2%) with saltiness (*P≤0.001*). This age cohort only perceived the control and samples reduced sodium sea salt 1.0%, NaCl 0.0%, MSG 0.1% and reduced sodium sea salt 1.0%, NaCl 0.0%, MSG 0.2% as being salty (*P≤0.001*). MSG levels of 0.1% and 0.2% with the addition of reduced sodium sea salt gave this age cohort a saltiness perception equal to that of the control sample, which contained 2.5% NaCl. Fat and salt combined are characteristic of cooked sausage flavour. In a study examining how the sensory characteristics of frankfurters were affected by fat, salt, and pH reduction, it was observed that saltiness of frankfurters were associated with fat content (Matulis, et al., 1995). Samples containing reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.1%, reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.2%, reduced sodium sea salt 0.0%, NaCl1.0%, MSG 0.3% and reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.1% were not liked for their salty flavour, however, reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.1% was liked for its spicy flavour (*P≤0.01*). In contrast, sausage samples containing reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.2% were not associated with spiciness (*P≤0.05*). The sausage sample containing reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.2% was also associated with meat flavour (*P≤0.05*). The sausage sample which included reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.3% was not linked with saltiness or meat flavour (*P≤0.01*). MSG adds an umami taste quality to food which improves palatability (Bellisle et al., 1991). An addition of 0.1% MSG influenced this age cohort's sensory perception, particularly in relation to flavour and spiciness.

6.3.3.3 Forty-one to sixty age category

The 41-60 age cohort were more accepting of the novel formulations. They liked the sausage sample containing reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.2% and the sample containing reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.3% ($P \leq 0.01$) ($P \leq 0.001$) for flavour, respectively, but did not like the flavour of the sample which contained reduced sodium sea salt 1.0%, NaCl 0.0%, MSG 0.2%. The sausage sample which contained reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.3% was the sample most accepted by this age cohort ($P \leq 0.05$). This age cohort had a greater acceptance for the sample containing reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.2% than the sample containing reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.3%, as can be seen in the bottom right-hand quadrant presented in Fig 4.1. Panellists in this age bracket did not like the saltiness of the control sample ($P \leq 0.01$). From Fig 4.3., it can be seen that saltiness and the control sample are located far apart. This age cohort did not associate the samples with only MSG as being salty. This age cohort had the greatest salt perception for sausage samples containing reduced sodium sea salt and MSG and that containing NaCl and MSG. The reduced sodium sea salt samples required 0.2% and 0.3% MSG to be perceived as salty, whereas 0.1 and 0.3% MSG was required in NaCl-containing sausage samples in order to increase the saltiness perception for this age cohort.

They did not consider some of the sausage samples which included reduced sodium sea salt, used at a level of 1.0%, as being spicy (reduced sodium sea salt 1.0%, NaCl 0.0%, MSG 0.2%) and (reduced sodium sea salt 1.0%, NaCl 0.0%, MSG 0.3%). The sausage sample which had reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.2% was associated with spiciness ($P \leq 0.01$) and metallic flavour ($P \leq 0.05$). Sausages containing reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.2% were thought to have a spicy and metallic flavour ($P \leq 0.01$) & ($P \leq 0.05$), respectively. Sausages which contained reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.3% was linked with spiciness and off-flavour ($P \leq 0.01$) and ($P \leq 0.01$), respectively. This age cohort was less influenced than the ≤20 and the 21-40 age cohorts when it came to MSG addition. The results obtained from assessment of the 41-60 age cohorts were more variable and surprising, for example, they failed to recognise the saltiness of the control sample. Most of the research that has found correlations between sensory threshold differences are based on a young and the elderly age cohort. Difference thresholds were found to occur in the ability to discriminate between young and the elderly subjects in a study carried out by Gilmore & Murphy (1989). They found that young subjects needed a 34% difference in concentration to perceive a difference in the bitterness of caffeine, whereas the elderly required a 74% increase. Schiffman (1993) demonstrated that young subjects needed 6-12% difference in a concentration of NaCl to perceive change, whereas the elderly required 25% difference to be able to distinguish a change in taste. Nordin et al. (2003) found that the threshold for citric acid and NaCl were larger in older individuals. In this study, participant age means were as follows: The elderly women: 71.4 yrs. old, the elderly men 70.3 yrs. old, young women 20.1 yrs. old and young men 19.4 yrs. old. The data presented in this current study suggests that the 41-60 age cohort were less sensitive to changes in salt than younger cohorts. Very little research to date has focused on middle age-related sensory threshold differences. Cohen & Gitman (1959) reported no significant general decrement in taste recognition, but their data seem to indicate a significant loss of sensitivity for NaCl between those aged 18–39 and those aged 40–64. Further research should be conducted into the decrement of salt recognition in the middle age cohort.

6.3.3.4 Sixty-one to sixty-five age category

Hedonic results for those aged 61-65 yrs. old are shown in Table 6.9. The 61-65 age category liked sausage samples containing the following ingredients; reduced sodium sea salt 0.0 %, NaCl 1.0%, MSG 0.2%, reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.1%, reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.2%, reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.3% for flavour and acceptability. This age cohort liked the flavour of the 0.1-0.3% MSG samples with no added extra salt or reduced sodium sea salt. They also liked sausage samples containing reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.1%, reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.2%, reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.3% for tenderness ($P \leq 0.01$) and they correlated sausage samples containing reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.2% with acceptability ($P \leq 0.01$). Saltiness influences tenderness, juiciness and mouthfeel. This age cohort exhibited various preferences for hedonic attributes based on the presence of NaCl. This age cohort did not perceive the samples without reduced sodium sea salt and NaCl as being salty. MSG on its own did not increase the perception of saltiness. This age cohort associated the sample containing reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.3% with saltiness. The most accepted samples for flavour were samples containing 0.1, 0.2 and 0.3% MSG and no added NaCl or reduced sodium sea salt. They preferred samples containing only MSG. This cohort also preferred the texture of sausage samples containing MSG and NaCl, including; reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.1%, reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.2% and reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.3%.

6.3.3.5 Sixty-six to seventy-five age category

The 66-75 age category disliked the flavour of sausage samples containing reduced sodium sea salt 1.0%, NaCl 0.0%, MSG 0.3% and reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.3%, both of which contained 0.3% MSG ($P \leq 0.01$). This age category also associated sausages containing reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.2% and reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.3% with firmness and texture, indicating that firmness in sausages is a desirable texture for this age group. This age group may prefer a firmer sausage texture, as ill-fitting dentures, dysphagia, or a reduced saliva flow are common problems as the aging process occurs. All of these symptoms are factors influencing textural perception. Sausages which contained reduced sodium sea salt 1.0%, NaCl 0.0%, MSG 0.1% was not liked for saltiness or meat flavour ($P \leq 0.01$). Sausages containing Reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.1%, reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.1%, reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.2% and reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.3% were not associated with saltiness. This age cohort did not perceive the samples without reduced sodium sea salt and NaCl as being salty. MSG on its own did not increase the perception of saltiness. This age cohort associated the sample which contained reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.3% with having a salty flavour. Sausage samples which contained reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.2% was linked with meat flavour ($P \leq 0.001$) and with metallic flavour ($P \leq 0.01$). The sample which included reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.3% was associated with having a spicy and metallic flavour ($P \leq 0.01$), but not with possessing a meat flavour ($P \leq 0.01$). The addition of MSG at a level of 0.3% led to a greater dislike for sausages by the 66-75 age cohort.

6.3.3.4 Seventy-six to eighty age category

The 76-80 age cohort presented an opposite result to that presented by the 66-75 age cohort. This age cohort liked sausage flavour for samples containing reduced sodium sea salt and 0.3% MSG (reduced sodium sea salt 1.0%, NaCl 0.0%, MSG 0.3%). Sausages which contained reduced sodium sea salt 1.0%, NaCl 0.0%, MSG 0.3% was liked for flavour ($P \leq 0.05$), so too was the sample which contained reduced sodium sea salt 0.0%, NaCl 0.0 %, MSG 0.3%. This age group also liked sausages containing reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.2% and reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.1% for flavour ($P \leq 0.05$). Sausages containing reduced sodium sea salt 0.0%, NaCl 1.0%, MSG 0.3% were not accepted by this age cohort, including flavour ($P \leq 0.05$). This age cohort also did not like the flavour of sausages containing high MSG (0.3%) and salt (1.0%), as can be seen from Fig 6.3. Flavour enhancement of 0.3% MSG was perceived as a positive formulation measure amongst this age cohort. Flavour enhancement was found to improve immunity and grip strength, in a study of the elderly subjects at a retirement home. Residents had an improved immune status determined by their T and B cell count when food was flavour enhanced. It also led to an improved grip strength in subjects (Schiffman & Warwick, 1993). In a study examining the salt-reducing effect of the characteristic flavours other than umami of dried bonito stock, it was found that MSG can enhance salty flavour, although the NaCl concentration was reduced (Manabe, 2008). A 0.2% addition of MSG influenced this age cohort's sensory perception of the sausages. Particularly, when reduced sodium sea salt was used in product formulations. In a study carried out by Bellisle et al. (1991), the effects of MSG on familiar foods were investigated in a group of 65 institutionalised the elderly persons. MSG improved palatability ratings, with an optimum at 0.6%. Weekly tests of free intake showed that subjects fed experimental foods with 0.6% added MSG ate progressively more and faster, indicating increasing palatability with repeated exposure. It is concluded that MSG can act as a palatability enhancer. It can facilitate long-term intake in both young and the elderly persons. The sample containing reduced sodium sea salt 0.0%, NaCl 0.0%, MSG 0.1% was the only sample this age cohort associated with saltiness. This sample did not contain any salt additions of NaCl or reduced sodium sea salt. MSG at a level of 0.1% increased the liking of the saltiness flavour of this age cohort.

Table 6.8: Sensory analysis of hedonic results in subjects aged ≤20 yrs. old – 60 yrs. old

Age Cohort	Sample	Acceptability	Firmness	Flavour	Tenderness	Texture
≤20 yrs. old	**C**	0.854 ^{ns}	0.107 ^{ns}	0.967 ^{ns}	-0.355 ^{ns}	0.236 ^{ns}
	RNa1,N0,0.1	-0.351 ^{ns}	0.505 ^{ns}	-0.341 ^{ns}	0.014 **	0.556 ^{ns}
	RNa1,N0,0.2	0.930 ^{ns}	0.241 ^{ns}	0.660 ^{ns}	-0.489 ^{ns}	0.229 ^{ns}
	RNa1,N0,0.3	-0.389 ^{ns}	0.000 ***	-0.632 ^{ns}	0.883 ^{ns}	0.001 ***
	RNa0,N1,0.1	-0.036 *	0.891 ^{ns}	-0.029 *	0.041 *	-0.326 ^{ns}
	RNa0,N1,0.2	-0.561 ^{ns}	0.014 **	-0.712 ^{ns}	0.737 ^{ns}	0.539 ^{ns}
	RNa0,N1,0.3	-0.130 ^{ns}	0.661 ^{ns}	-0.002 **	0.730 ^{ns}	0.584 ^{ns}
	RNa0,N0,0.1	0.946 ^{ns}	0.081 ^{ns}	0.098 ^{ns}	-0.299 ^{ns}	0.681 ^{ns}
	RNa0,N0,0.2	-0.387 ^{ns}	0.211 ^{ns}	-0.007 **	0.024 *	-0.214 ^{ns}
	RNa0,N0,0.3	-0.740 ^{ns}	0.459 ^{ns}	0.424 ^{ns}	0.009 **	0.248 ^{ns}
21-40 yrs. old	**C**	-0.773 ^{ns}	0.319 ^{ns}	-0.112 ^{ns}	0.000 ***	-0.238 ^{ns}
	RNa1,N0,0.1	-0.059 ^{ns}	0.001 ***	-0.004 **	0.000 ***	0.769 ^{ns}
	RNa1,N0,0.2	-0.973 ^{ns}	0.849 ^{ns}	-0.923 ^{ns}	0.001 ***	0.914 ^{ns}
	RNa1,N0,0.3	-0.048 *	0.589 ^{ns}	0.001 ^{ns}	-0.756 ***	-0.883 ^{ns}
	RNa0,N1,0.1	0.461 ^{ns}	0.276 ^{ns}	0.071 ^{ns}	-0.000 ***	0.507 ^{ns}
	RNa0,N1,0.2	0.165 ^{ns}	0.809 ^{ns}	0.256 ^{ns}	-0.010 **	0.128 ^{ns}
	RNa0,N1,0.3	0.302 ^{ns}	0.158 ^{ns}	0.384 ^{ns}	-0.010 **	0.321 ^{ns}
	RNa0,N0,0.1	0.436 ^{ns}	0.077 ^{ns}	0.009 **	-0.010 **	0.719 ^{ns}
	RNa0,N0,0.2	-0.272 ^{ns}	0.024 *	-0.027 *	0.216 ^{ns}	0.322 ^{ns}
	RNa0,N0,0.3	0.469 ^{ns}	0.015 *	0.939 ^{ns}	-0.010 **	0.537 ^{ns}
41-60 yrs. old	**C**	0.355 ^{ns}	0.722 ^{ns}	0.443 ^{ns}	-0.009 **	0.065 ^{ns}
	RNa1,N0,0.1	-0.411 ^{ns}	0.829 ^{ns}	-0.994 ^{ns}	0.573 ^{ns}	0.177 ^{ns}
	RNa1,N0,0.2	-0.064 ^{ns}	0.155 ^{ns}	-0.000 ***	0.000 ***	0.865 ^{ns}
	RNa1,N0,0.3	-0.936 ^{ns}	0.228 ^{ns}	-0.435 ^{ns}	0.001 ***	-0.745 ^{ns}
	RNa0,N1,0.1	-0.965 ^{ns}	0.084 ^{ns}	-0.013 *	0.001 ***	0.914 ^{ns}
	RNa0,N1,0.2	0.708 ^{ns}	0.013 **	0.004 **	-0.773 ^{ns}	0.049 *
	RNa0,N1,0.3	0.203 ^{ns}	0.051 *	0.598 ^{ns}	-0.000 ***	0.507 ^{ns}
	RNa0,N0,0.1	0.436 ^{ns}	0.006 **	0.498 ^{ns}	0.365 ^{ns}	0.527 ^{ns}
	RNa0,N0,0.2	0.336 ^{ns}	0.846 ^{ns}	0.928 ^{ns}	-0.011 **	0.281 ^{ns}
	RNa0,N0,0.3	0.026 *	0.055 ^{ns}	0.000 ***	-0.010 **	0.619 ^{ns}

The sign dictates whether the correlation is positively or negatively correlated significance of regression coefficients; ^{ns} = non-significant, * = (P≤0.05), ** = (P≤0.01), *** = (P≤0.001).

F: % of Fat, S: % of NaCl, RNa: % of Reduced Na salt

Table 6.8: Sensory analysis of intensity results in subjects aged ≤20 yrs. old – 60 yrs. old

Age Cohort	Sample	Saltiness	Spiciness	Meat Flavour	Metallic Flavour	Off Flavour
≤20	**C**	-0.355 ns	0.967 ns	-0.107 ns	0.236 ns	0.854 ns
	RNa1,N0,0.1	0.014 **	-0.341 ns	0.505 ns	-0.556 ns	-0.351 ns
	RNa1,N0,0.2	-0.489 ns	0.660 ns	-0.241 ns	0.229 ns	0.930 ns
	RNa1,N0,0.3	0.883 ns	-0.632 ns	0.000 ***	-0.001 ***	-0.389 ns
	RNa0,N1,0.1	0.041 ns	-0.029 *	0.891 ns	-0.326 ns	-0.036 *
	RNa0,N1,0.2	0.737 ns	-0.712 ns	0.014 **	-0.539 ns	-0.561 ns
	RNa0,N1,0.3	0.730 ns	-0.002 **	0.661 ns	-0.584 ns	-0.130 ns
	RNa0,N0,0.1	-0.299 ns	0.098 ns	-0.081 ns	0.681 ns	0.946 ns
	RNa0,N0,0.2	0.024 *	-0.007 **	0.211 ns	-0.214 ns	-0.387 ns
	RNa0,N0,0.3	0.009 **	-0.424 ns	0.459 ns	-0.248 ns	-0.740 ns
21-40	**C**	0.000 ***	-0.112 ns	0.319 ns	-0.238 ns	-0.773 ns
	RNa1,N0,0.1	0.000 ***	-0.004 *	0.001 ***	-0.769 ns	-0.050 *
	RNa1,N0,0.2	0.001 ***	-0.923 ns	0.849 ns	-0.914 ns	-0.973 ns
	RNa1,N0,0.3	0.756 ns	-0.001 ***	0.589 ns	-0.883 ns	-0.048 *
	RNa0,N1,0.1	-0.000 ***	0.071 ns	-0.276 ns	0.507 ns	0.461 ns
	RNa0,N1,0.2	-0.010 **	0.256 ns	-0.809 ns	0.128 ns	0.165 ns
	RNa0,N1,0.3	-0.010 **	0.384 ns	-0.158 ns	0.321 ns	0.302 ns
	RNa0,N0,0.1	-0.010 **	0.009 **	-0.077 ns	0.719 ns	0.436 ns
	RNa0,N0,0.2	0.216 ns	-0.027 *	0.024 *	-0.322 ns	-0.272 ns
	RNa0,N0,0.3	-0.010 **	0.939 ns	-0.01 **	0.537 ns	0.469 ns
41-60	**C**	-0.009 **	0.443 ns	-0.722 ns	0.065 ns	0.355 ns
	RNa1,N0,0.1	0.573 ns	-0.994 ns	0.829 ns	-0.177 ns	-0.411 ns
	RNa1,N0,0.2	0.000 ***	-0.000 ***	0.155 ns	-0.865 ns	-0.064 ns
	RNa1,N0,0.3	0.001 ***	-0.435 ns	0.228 ns	-0.745 ns	-0.936 ns
	RNa0,N1,0.1	0.001 ***	-0.013 **	0.084 ns	-0.914 ns	-0.965 ns
	RNa0,N1,0.2	-0.773 ns	0.004 **	-0.013 **	0.049 *	0.708 ns
	RNa0,N1,0.3	0.000 ***	0.598 ns	-0.051 *	0.507 ns	0.203 ns
	RNa0,N0,0.1	-0.365 ns	0.498 ns	-0.006 **	0.527 ns	0.436 ns
	RNa0,N0,0.2	-0.011 **	0.928 ns	-0.846 ns	0.281 ns	0.336 ns
	RNa0,N0,0.3	-0.010 **	0.000 ***	-0.05 *	0.619 ns	0.026 *

The sign dictates whether the correlation is positively or negatively correlated significance of regression coefficients; ns = non-significant, * = (P≤0.05), ** = (P≤0.01), *** = (P≤0.001).

RNa = Reduced Sodium Salt, N= NaCl

Table 6.9: Sensory analysis of hedonic results in subjects aged 61 yrs. old – 85 yrs. old

Age Cohort	Sample	Tenderness	Flavour	Firmness	Texture	Acceptability
61-65 yrs. old	**C**	0.531 ns	-0.195 ns	0.595 ns	0.018*	-0.056 ns
	RNa1,N0,0.1	-0.177 ns	0.341 ns	0.775 ns	0.128 ns	0.563 ns
	RNa1,N0,0.2	-0.008**	0.021 ns	0.122 ns	0.000***	0.021*
	RNa1,N0,0.3	0.579 ns	-0.115 ns	0.873 ns	0.000***	-0.299 ns
	RNa0,N1,0.1	0.000***	-0.964 ns	0.563 ns	-0.024*	-0.391 ns
	RNa0,N1,0.2	0.001***	0.001***	0.212 ns	0.048*	0.007**
	RNa0,N1,0.3	0.001***	-0.315 ns	0.110 ns	0.064 ns	-0.629 ns
	RNa0,N0,0.1	-0.010**	0.032*	0.063 ns	0.005**	0.043*
	RNa0,N0,0.2	-0.898 ns	0.014**	0.612 ns	0.622 ns	0.029*
	RNa0,N0,0.3	-0.113 ns	0.000***	0.929 ns	0.456 ns	0.023*
66-75 yrs. old	**C**	0.244 ns	0.497 ns	0.428 ns	0.519 ns	0.742 ns
	RNa1,N0,0.1	-0.011**	0.333 ns	0.033*	0.531 ns	0.248 ns
	RNa1,N0,0.2	-0.062 ns	0.146 ns	0.298 ns	0.418 ns	0.416 ns
	RNa1,N0,0.3	0.299 ns	-0.015**	0.835 ns	0.937 ns	-0.109 ns
	RNa0,N1,0.1	-0.011**	0.831 ns	0.395 ns	0.614 ns	0.736 ns
	RNa0,N1,0.2	0.166 ns	-0.696 ns	0.304 ns	-0.325 ns	-0.576 ns
	RNa0,N1,0.3	0.002**	-0.066 ns	0.229 ns	-0.492 ns	-0.621 ns
	RNa0,N0,0.1	-0.003**	0.892 ns	0.317 ns	0.184 ns	0.293 ns
	RNa0,N0,0.2	-0.056 ns	0.978 ns	0.042*	0.011**	0.666 ns
	RNa0,N0,0.3	-0.008**	-0.010**	0.003**	0.010**	0.579 ns
76-85 yrs. old	**C**	-0.068 ns	0.328 ns	0.012**	0.816 ns	0.495 ns
	RNa1,N0,0.1	-0.068 ns	0.495 ns	0.328 ns	0.020*	0.104 ns
	RNa1,N0,0.2	0.217 ns	-0.272 ns	0.459 ns	0.733 ns	-0.424 ns
	RNa1,N0,0.3	-0.070 ns	0.020*	0.182 ns	0.803 ns	0.140 ns
	RNa0,N1,0.1	0.072 ns	0.019*	0.038*	0.228 ns	0.071 ns
	RNa0,N1,0.2	0.300 ns	-0.213 ns	0.435 ns	0.290 ns	-0.240 ns
	RNa0,N1,0.3	0.072 ns	-0.016*	0.373 ns	0.431 ns	-0.039*
	RNa0,N0,0.1	0.036*	-0.382 ns	0.459 ns	0.618 ns	-0.539 ns
	RNa0,N0,0.2	-0.835 ns	0.015*	0.832 ns	0.094 ns	0.061 ns
	RNa0,N0,0.3	0.013**	0.015*	0.016*	0.081 ns	0.109 ns

The sign dictates whether the correlation is positively or negatively correlated significance of regression coefficients; ^{ns} = non-significant, * = ($P \leq 0.05$), ** = ($P \leq 0.01$), *** = ($P \leq 0.001$).RNa= Reduced Sodium Salt, N= NaCl

Table 6.10: Sensory analysis of intensity results in subjects aged 61-85 yrs. old

The sign dictates whether the correlation is positively or negatively correlated significance of regression

Age Cohort	Sample	Saltiness	Spiciness	Meat Flavour	Metallic Flavour	Off Flavour
61-65	**C**	0.531 ^{ns}	-0.195 ^{ns}	0.595 ^{ns}	-0.010 **	-0.05 *
	RNa1,N0,0.1	-0.177 ^{ns}	0.341 ^{ns}	-0.775 ^{ns}	0.128 ^{ns}	0.563 ^{ns}
	RNa1,N0,0.2	-0.008 **	0.021 *	-0.122 ^{ns}	0.000 ***	0.021 *
	RNa1,N0,0.3	0.579 ^{ns}	-0.115 ^{ns}	0.873 ^{ns}	-0.000 ***	-0.299 ^{ns}
	RNa0,N1,0.1	0.000 ***	-0.964 ^{ns}	0.563 ^{ns}	-0.024 *	-0.391 ^{ns}
	RNa0,N1,0.2	-0.001 ***	0.001 ***	-0.212 ^{ns}	0.048 *	0.007 **
	RNa0,N1,0.3	0.001 ***	-0.315 ^{ns}	0.110 ^{ns}	-0.064 ^{ns}	-0.629 ^{ns}
	RNa0,N0,0.1	-0.010 **	0.032 *	-0.063 ^{ns}	0.005 **	0.043 *
	RNa0,N0,0.2	-0.898 ^{ns}	0.014 **	-0.612 ^{ns}	0.622 ^{ns}	0.029 *
	RNa0,N0,0.3	-0.113 ^{ns}	0.000 ***	-0.929 ^{ns}	0.456 ^{ns}	0.023 *
66-75	**C**	0.244 ^{ns}	-0.497 ^{ns}	0.428 ^{ns}	-0.519 ^{ns}	-0.742 ^{ns}
	RNa1,N0,0.1	-0.011 **	0.333 ^{ns}	-0.033 **	0.531 ^{ns}	0.248 ^{ns}
	RNa1,N0,0.2	-0.062 ^{ns}	0.146 ^{ns}	-0.298 ^{ns}	0.418 ^{ns}	0.416 ^{ns}
	RNa1,N0,0.3	0.299 ^{ns}	-0.015 **	0.835 ^{ns}	-0.936 ^{ns}	-0.109 ^{ns}
	RNa0,N1,0.1	-0.011 **	0.831 ^{ns}	-0.395 ^{ns}	0.614 ^{ns}	0.736 ^{ns}
	RNa0,N1,0.2	0.166 ^{ns}	-0.696 ^{ns}	0.304 ^{ns}	-0.325 ^{ns}	-0.576 ^{ns}
	RNa0,N1,0.3	0.002 **	-0.066 ^{ns}	0.229 ^{ns}	-0.492 ^{ns}	-0.621 ^{ns}
	RNa0,N0,0.1	-0.003 **	0.892 ^{ns}	-0.317 ^{ns}	0.184 ^{ns}	0.293 ^{ns}
	RNa0,N0,0.2	-0.05 *	0.978 ^{ns}	-0.042 *	0.011 **	0.666 ^{ns}
	RNa0,N0,0.3	-0.008 **	0.010**	-0.003 **	0.010 **	0.579 ^{ns}
76-85	**C**	-0.068 ^{ns}	0.328 ^{ns}	-0.012 **	0.816 ^{ns}	0.495 ^{ns}
	RNa1N0M0.1	-0.068 ^{ns}	0.495 ^{ns}	-0.328 ^{ns}	0.020 *	0.104 ^{ns}
	RNa1N0M0.2	0.217 ^{ns}	-0.272 ^{ns}	0.459 ^{ns}	-0.733 ^{ns}	-0.424 ^{ns}
	RNa1N0M0.3	-0.070 ^{ns}	0.020 *	-0.182 ^{ns}	0.803 ^{ns}	0.140 ^{ns}
	RNa0N1M0.1	-0.072 ^{ns}	0.01 **	-0.038 *	0.228 ^{ns}	0.071 ^{ns}
	RNa0N1M0.2	0.300 ^{ns}	-0.213 ^{ns}	0.435 ^{ns}	-0.290 ^{ns}	-0.240 ^{ns}
	RNa0N1M0.3	0.072 ^{ns}	-0.01 **	0.373 ^{ns}	-0.431 ^{ns}	-0.039 *
	RNa0N0M0.1	0.036 *	-0.382 ^{ns}	0.459 ^{ns}	-0.618 ^{ns}	-0.539 ^{ns}
	RNa0N0M0.2	-0.835 ^{ns}	0.01 **	-0.832 ^{ns}	0.094 ^{ns}	0.061 ^{ns}
	RNa0N0M0.3	-0.013 **	0.01 **	-0.01 **	0.081 ^{ns}	0.109 ^{ns}

coefficients; ^{ns} = non-significant, * = ($P \leq 0.05$), ** = ($P \leq 0.01$), *** = ($P \leq 0.001$).

RNa = Reduced Sodium Salt, N= NaCl

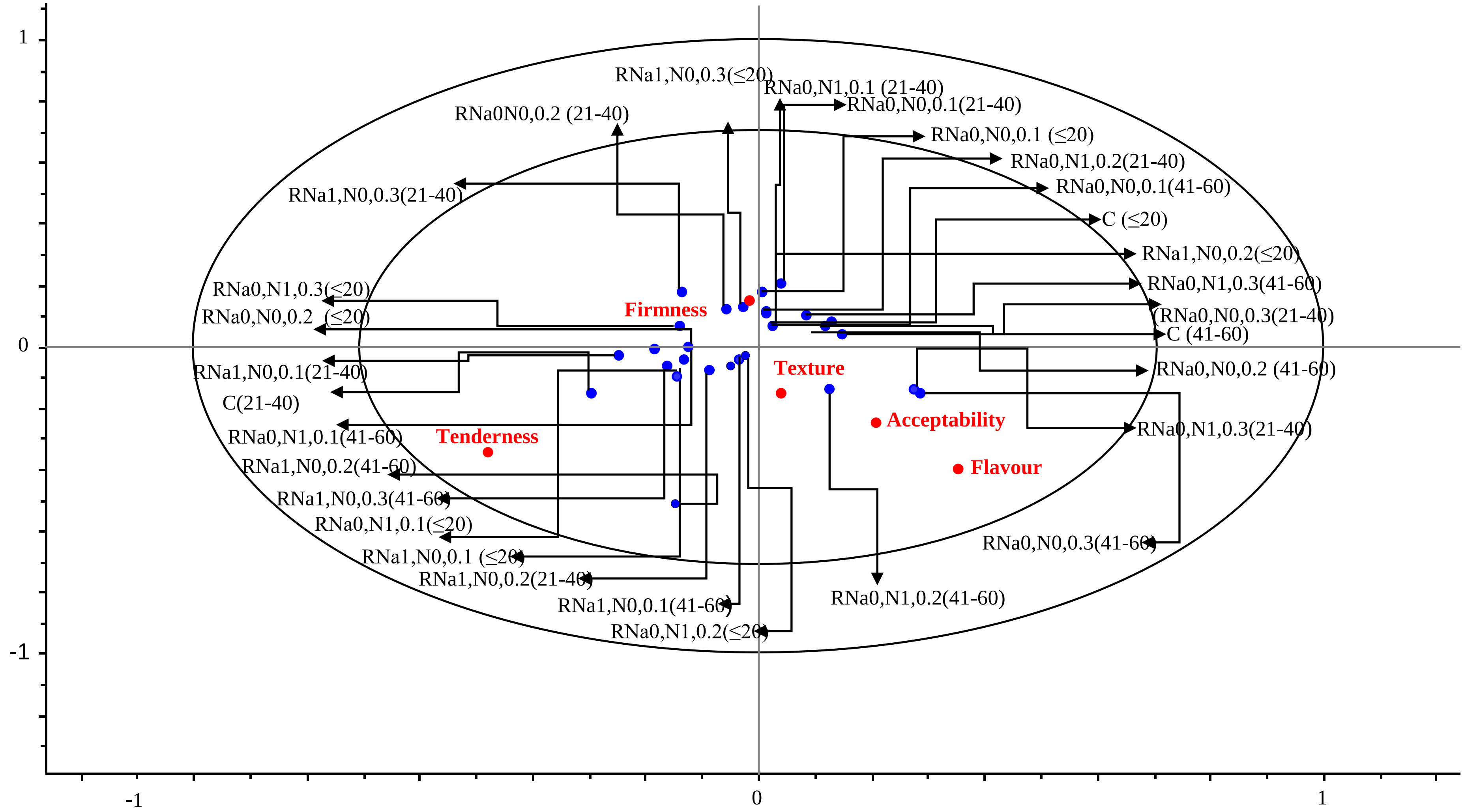

Figure 6.1: ANOVA – partial least squares regression (APLSR) correlation loading plot for each formulation, hedonic descriptor and age category (≤20 yrs. old – 60 yrs. old) RNa = Reduced Sodium Salt, N= NaCl

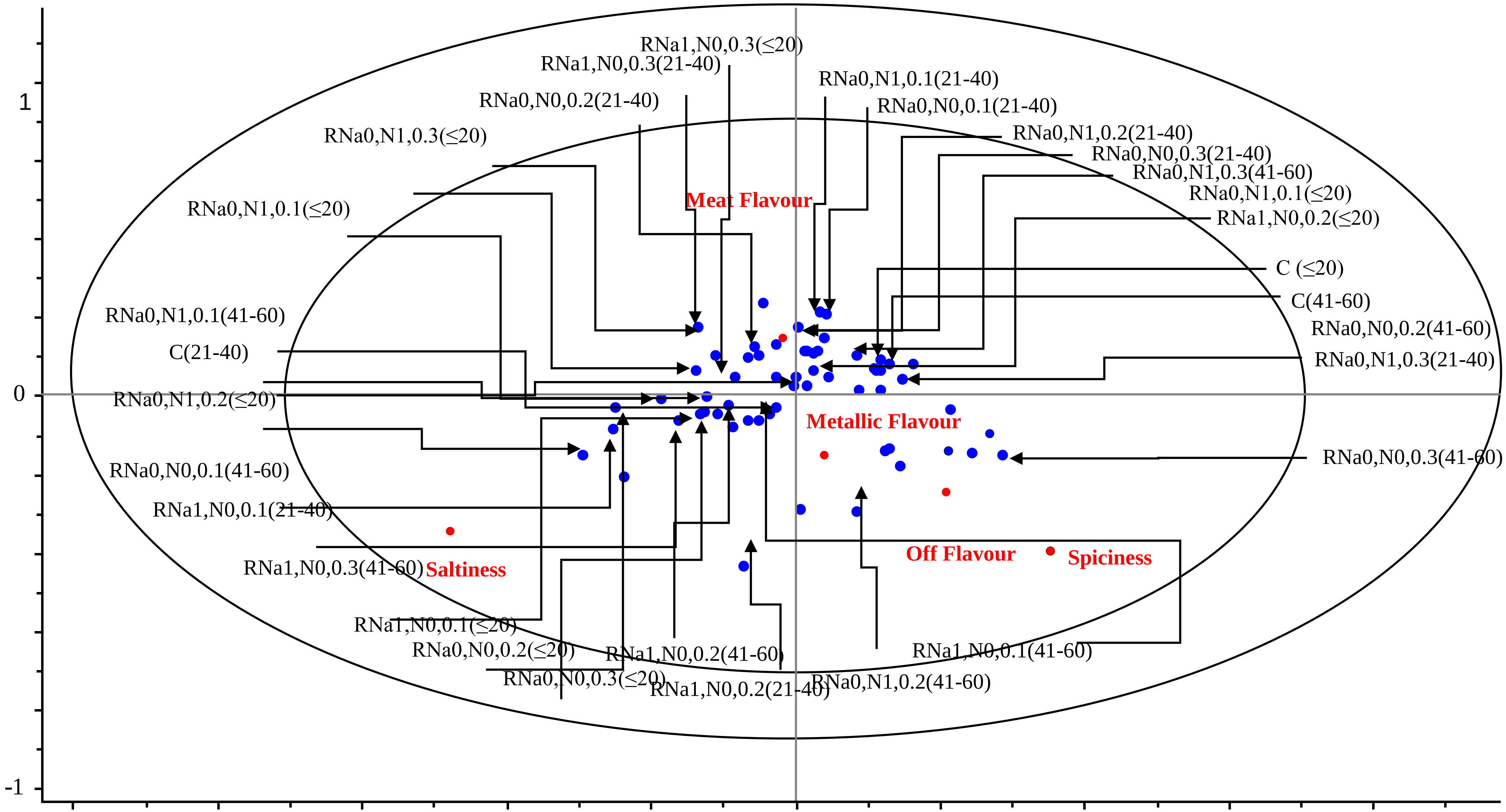

Figure 6.2: ANOVA – partial least squares regression (APLSR) correlation loading plot for each formulation, intensity descriptor and age category (≤20 yrs. old – 60 yrs. old) RNa = Reduced Sodium Salt, N= NaCl, M = MSG

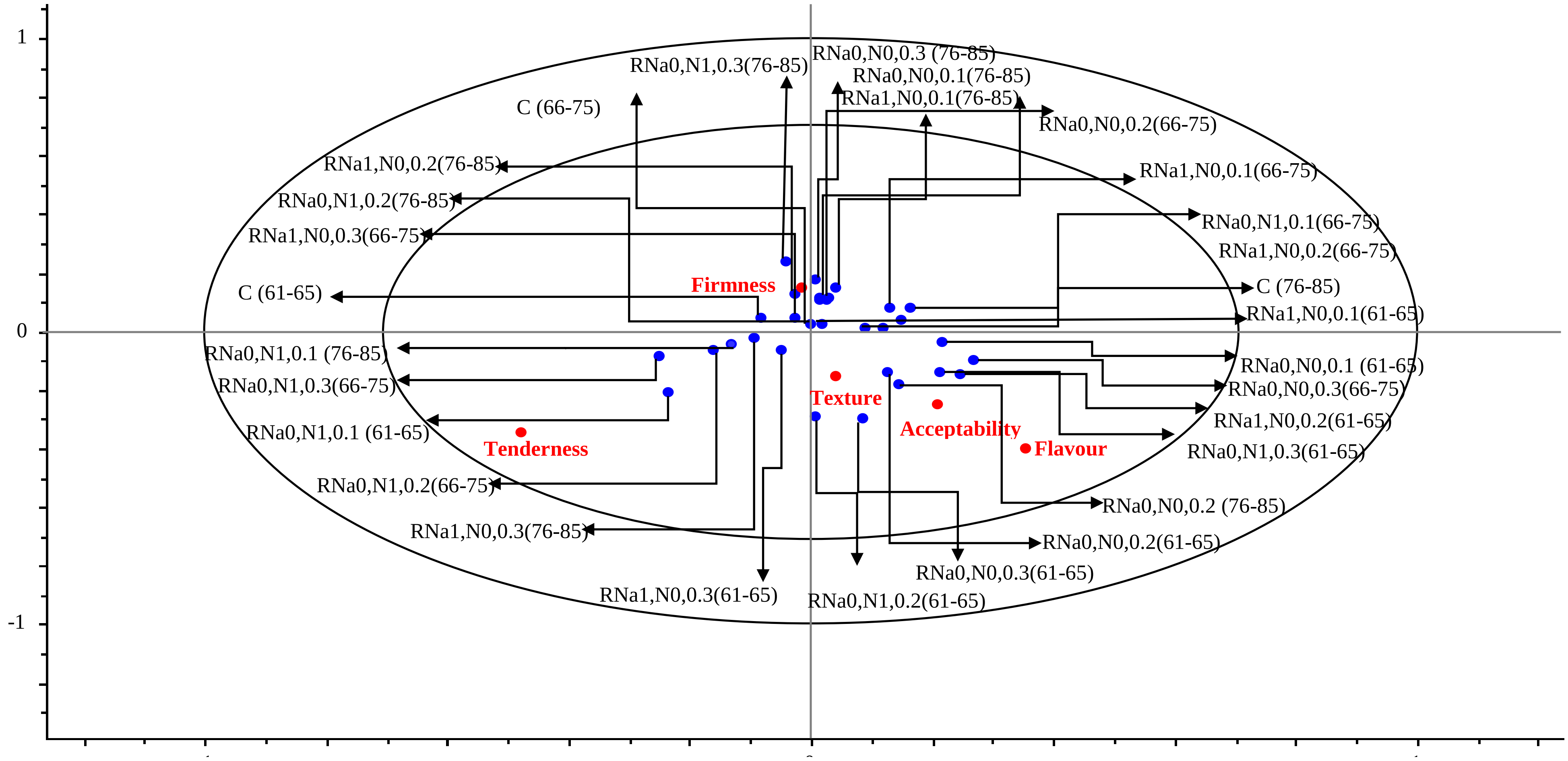

Figure 6.3: ANOVA – partial least squares regression (APLSR) correlation loading plot for each formulation, hedonic descriptors and age category (61-85 yrs. old) RNa =Reduced Sodium Salt, N= NaCl

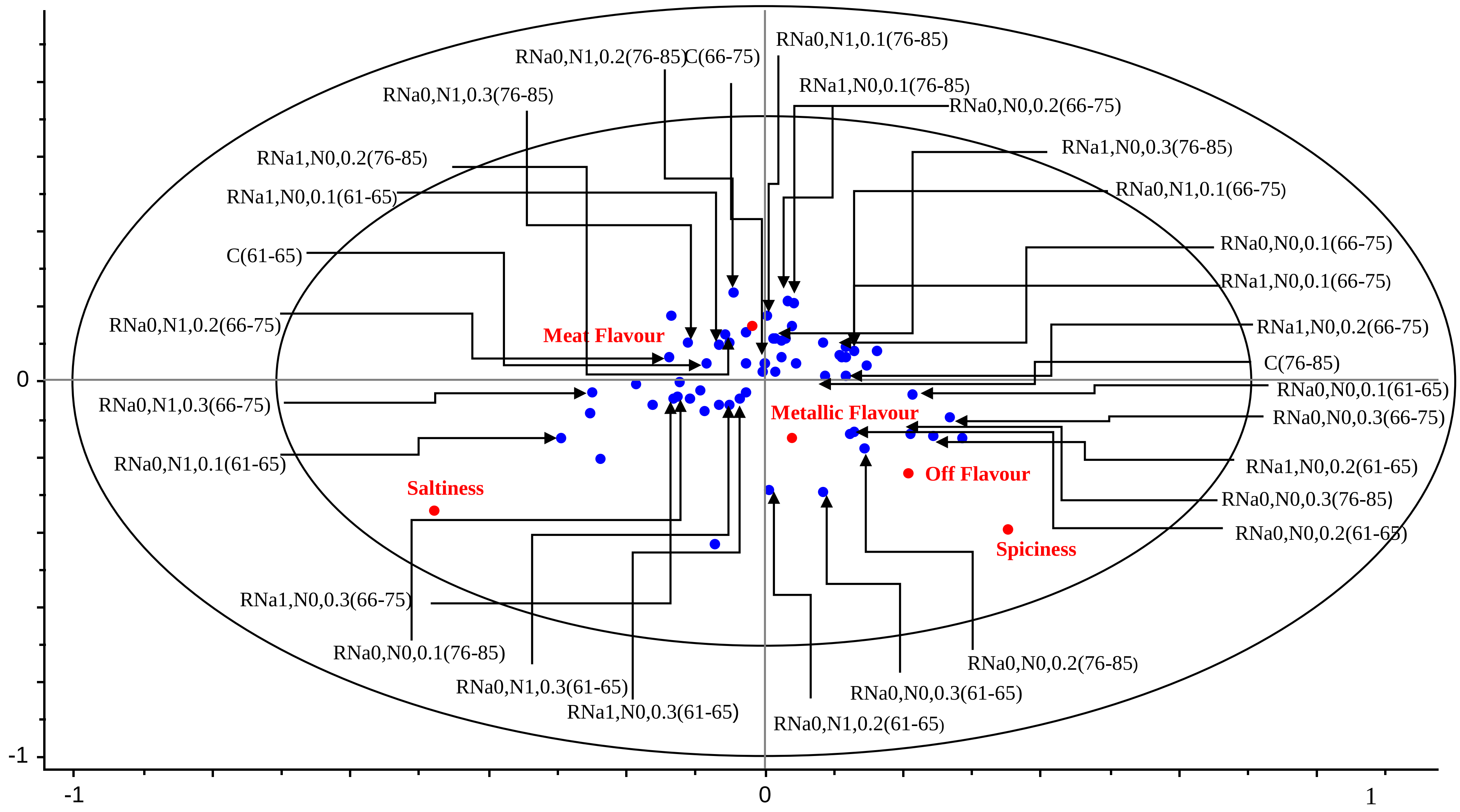

Figure 6.4: ANOVA – partial least squares regression (APLSR) correlation loading plot for each formulation, intensity descriptor and age category (61-85 yrs. old) RNa = Reduced Sodium Salt, N= NaCl

6.4. Conclusion

This study extends our knowledge of the hedonic and intensity effects MSG has on our perception as age progresses. The evidence from this study suggests that MSG has a varying effect on flavour perception for every age group from early twenties to middle eighties. By adding in 0.2% MSG to a sausage formulation, the perception of meat flavour increased within the under twenty age cohort. The 21-40 age cohort's sensory perception was influenced by a 0.1% change in MSG. The sensory results of the 41-60 age cohort were less precise than those aged under 40. Samples just featuring MSG were preferred for flavour than samples containing NaCl or reduced sodium sea salt, yet they preferred the texture of sausages containing MSG and NaCl. This study highlights a decline in NaCl threshold in those aged from 41-60. Future studies may further examine various taste threshold values of this age cohort with a view to determine if taste acuity becomes diminished during this age period. The 66-75 yr. olds did not like the samples that contained 0.3% MSG, whereas the 76-80 yr. olds did. The study also highlights the ability of MSG to enhance the salty perception of foods. Those aged ≤20 & 76-85 yrs associated samples with MSG and without any salt/salt replacer with a perception of saltiness. Those aged between 41-65 yrs. old linked the samples containing reduced sodium sea salt and MSG with saltiness and those aged between 61-75 yrs. old correlated the samples containing NaCl and MSG with saltiness perception. This study adds to the existing body of age-related sensory research, however, it uniquely highlights a sensory profile for MSG that may be used to develop low salt meat products. It provides evidence of the ability of MSG to enhance the saltiness perception of meat products and thus act as an effective salt replacer.

The study also highlighted the importance of texture as people entered the over sixty-year-old age bracket. The 61-65 and 66-75 yr. age cohorts were more influenced by texture than younger age cohorts. Texture was affected when physical composition analysis was carried out. A higher degree of chewiness was noted in sausages containing MSG in their formulation. They were also more resilient. The more senior age cohorts preferred a firmer texture in sausages. This further supports previous work conducted by the researchers involved in this study, which again shows, the importance of meat and meat product texture to older consumers. In conclusion, these findings enhance our understanding of the effects that MSG has on intensity and hedonic attributes and which are very specific to the age of the consumer. This information can be used to develop targeted interventions aimed at developing age-specific food products. Further research may explore other food stuffs or other salt-reduced food products.

CHAPTER 7

Quantitative Descriptive Analysis (QDA) of salt-and fat-reduced traditional breakfast sausages containing Monosodium Glutamate (MSG): Development of a flavour wheel

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Abstract

Consumer health awareness is driving demand for salt – and - fat reduced sausages; however the flavour profile of such products must also be optimal if such commodity items are to succeed in the marketplace. Quantitative Descriptive Analysis (QDA) was used to explore the sensory variation of ten sausage samples which included salt and fat reduced sausage and MSG (Monosodium glutamate) flavour enhanced sausages. A panel (n=8) was trained using a bespoke lexicon and a flavour wheel was generated for 15 attributes deemed to be most relevant to these products. Primary flavour differences between low - fat and low - salt sausages compared to a control sample were identified as: bitter, bland, chewy, crispy, drying, fatty, grainy, metallic, peppery, pork identity, salty, spicy, traditional sausage flavour, umami and warmed-over. This study presents a list of product attributes (lexicons) and a sensory wheel which may be used as a reference for describing fat and salt reduced pork sausages for applications in research in meat product development. MSG was found to reduce the perception of spiciness, by enhancing other attributes such as saltiness in sausages. Samples containing salt and 0.2% MSG was equal in salt perception to the control samples as determined by QDA.

Key Words: Salt reduction, Fat Reduction, Descriptive Analysis, Sensory Evaluation

7.1 Introduction

The way in which consumers perceive meat and meat products is the driving force influencing the profitability of meat industries. In recent years, a large concern has been expressed regarding the levels of salt and fat being added to processed meat products. Research into processed meat reformulation has resulted in many methods being employed to reduce salt and fat, including: reducing the total amount of salt or by (partly) substituting sodium chloride with potassium, magnesium and calcium chloride, glutamate, glycine and potassium lactate (Tobin, O'Sullivan, Hamill, & Kerry, 2012ab; Tobin, O'Sullivan, Hamill, & Kerry, 2013; Fellendorf, O'Sullivan, & Kerry, 2015; Fellendorf, O'Sullivan, & Kerry, 2016abc; Fellendorf, O'Sullivan, & Kerry, 2017) without affecting its sensory quality. Additionally, Chapter 6 has demonstrated the ability of MSG to enhance saltiness perception in breakfast sausages across various age cohorts. MSG is a useful salt reduction ingredient for the meat industry, as it allows the production of salt reduced meat products. Tenderness, juiciness, flavour and overall palatability remain the most sought - after attributes that drive consumer acceptance of meat products (Miller, Carr, Ramsey, Crockett, & Hoover, 2001). Descriptive tests are utilised to define and measure the attributes of the samples being evaluated and to produce a sensory profile. Quantitative descriptive analysis (QDA) has been recognised as a tool for measurement and optimisation of sensory attributes for various food products (Stone and Sidel 1998; Byrne, O'Sullivan, Bredie, Andersen, & Martens, 2003). The primary objective applying QDA is to facilitate training so that panellists have the ability to measure the specific quality attributes of the product under investigation in order to yield quantitative product description which can be analysed statistically. A focus group is utilised to identify product attributes and intensity scales specific to a product (Murray et al. 2001). The focus group is trained so that products and attributes can be identified. The terms allow for a precise description of the product attributes, which allows detailed profiling of sensory attributes. QDA can be utilised to predict consumer acceptability and it is also beneficial to product developers who need a clear outline of a product types. This allows product profiles to be compared across product types and across time, thereby providing the same level of confidence expected from instrumentally generated data. The developed profile is then used as a reference of a sample type and can be used to profile similar product changes with a view to identifying various similarities and differences between products. Many meat and meat product lexicons have been developed previously; chicken (Lyon, 1987), beef (Maughan, Tansawat, Cornforth, Ward, & Martini, 2012; & Adhikari et al., 2011), meat WOF (Johnson & Civille, 1986), mutton, rabbit (Blasco & Ouhayoun, 2010) and ham (Flores, Ingram, Bett, Toldra, & Spanier, 1997). However, such an approach has not been adopted for pork – sausages or sausage type products following review of the scientific literature. A standardised pork sausage flavor lexicon will have an immediate application in identifying the effects salt - and fat - reduction has on pork breakfast sausages.

The objectives of this chapter was to; 1) Recruit and train a panel using the Quantitative Descriptive Analysis Method, 2) Quantify differences between sausage treatments using a flavour profile, 3) Assess flavor - enhancing potential of MSG on NaCl and a reduced - sodium (45% less) salt 4) develop a standardised flavour lexicon and flavour wheel for fat and salt reduced pork sausages.

7.2. Materials and Methods

7.2.1 Sample Description

Sausages were manufactured using ingredients listed in Table 7.1. The product recipe employed in this study was established from Chapter 6. The formulations from this previous study were utilised for this current study and a control sample (000) was manufactured using a standardised traditional breakfast sausage recipe. The sensory attributes of the control sample were considered to be representative of the sensory profile typically associated with breakfast sausages. The control sample was used during the training and testing phase of the QDA. It served as a fixed point which all other samples could be compared to, thereby allowing panellists to calibrate their sensory perception at the start of each training and testing session.

7.2.2 Sample Manufacture

Fresh boneless pork and pork back fat were purchased from local meat processors (Ballyburden Meats Ltd, Ballincollig, Cork, Ireland). All meat purchased had full traceability. The meat and fat were cut, weighed and vacuum packed accordingly. They were stored in the freezer (-18°C). Prior to use, the meat and fat were thawed slightly at refrigerated temperature (4°C) before being minced through a 10mm plate (TALSABELL S. A.,Pol. Ind. V. Salud, 8. Valencia, Spain). The reduced sodium salt composed of 45% reduced sodium. The pork, seasoning (0% sodium), salt, pea starch, MSG, reduced sodium and a third of the required water were fed into a bowel chopper and mixed at high speed for 45s. Having formed the base emulsion, the required fat was then added to the bowel chopper (Maschinenfabrik Seydelmann KG, Aalen (Wurtt), Burgstallstrabe, Germany) and the mix was chopped for a further 45s. at high speed. The remaining water was added and the batter mixed for a further 30s. at high speed. Finally, the pin-head rusk was added to the batter and mixed again for 30s at low speed. The sausage mix was then loaded into the sausage filler, (Mainca, Mod EB 12/25 MAINCA, Maquinaria Industria Carnica Equipamientos Carnicos, S.L. Granollers, Barcelona, Spain) from where it was fed into collagen casings. The sausages were the sealed in plastic bags and refrigerated (4°C) overnight to allow product equilibration. Nine treatment batches were manufactured three individual times.

Table 7.1: Sausage Formulations

%	000	RNa 1N0M0.1	RNa 1N0M0.2	RNa 1N0M0.3	RNa 0N1M0.1	RNa 0N1M0.2	RNa 0N1M0.3	RNa 0N0M0.1	RNa 0N0M0.2	RNa 0N0M0.3
MSG	0	0.1	0.2	0.3	0.1	0.2	0.3	0.1	0.2	0.3
NaCl	2.5	0	0	0	1	1	1	0	0	0
RNa	0	1	1	1	0	0	0	0	0	0
Fat	30	15	15	15	15	15	15	15	15	15
Pea	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pork	35	35	35	35	35	35	35	35	35	35
Rusk	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Seasoning	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Water	17.5	33.4	33.3	33.2	33.4	33.3	33.2	34.4	34.3	34.2

000: Control, RNa = Reduced Sodium Salt, N: NaCl, MSG = Monosodium Glutamate

7.2.3 Sensory

7.2.3.1 Screening part 1

Figure 7.1 outlines the process of recruitment, training and sensory analysis of panellists. Panellists were initially screened using an online structures questionnaire. Of the 730 respondents 103 were identified as eligible to attend the sensory screening component. The session took place in a lecture theatre in University College Cork (UCC). The panellist's ability to follow directions and making concise judgements were monitored using scaling tests, and matching tests of taste and aroma. Ranking tests were used to determine the candidates ability to discriminate levels of intensities according to Meilgaard et al., (2006). The following difference testing: triangle testing, duo trio testing, basic taste testing, taste intensity and odour recognition testing were conducted on the panellists. Session 2 featured screening of terms & grouping terms by consensus whereby 36 attributes were generated.The term generation was monitored using a PCA (Fig 7.2). Session 3 involved a scaling exercise with the participants.

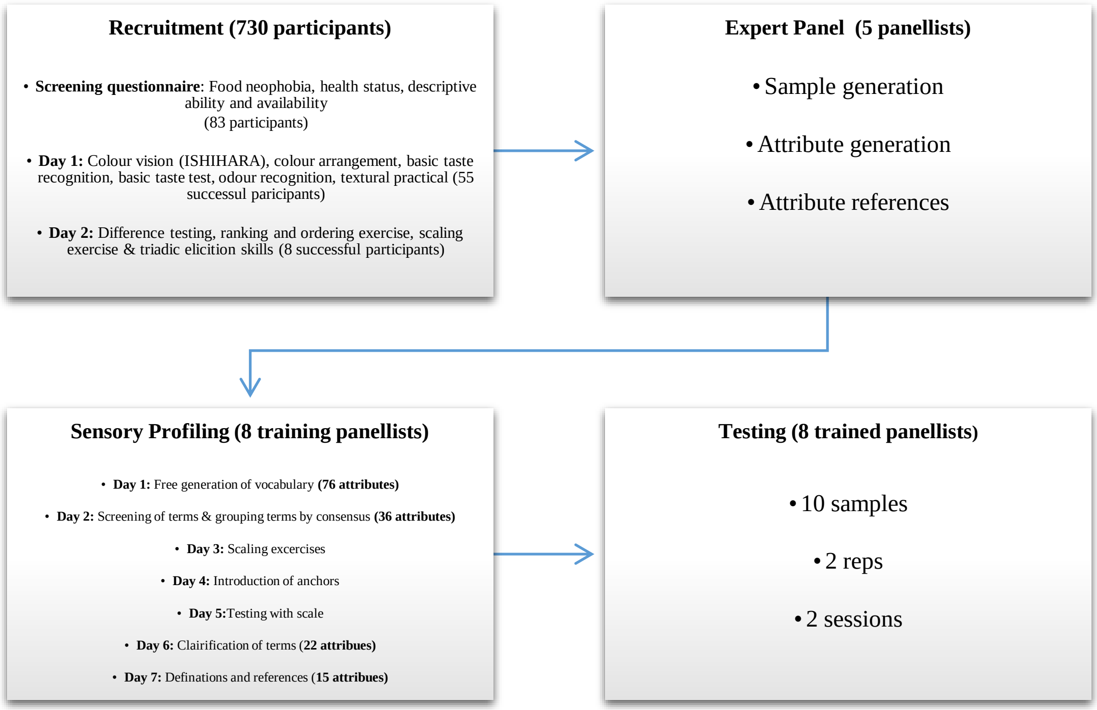
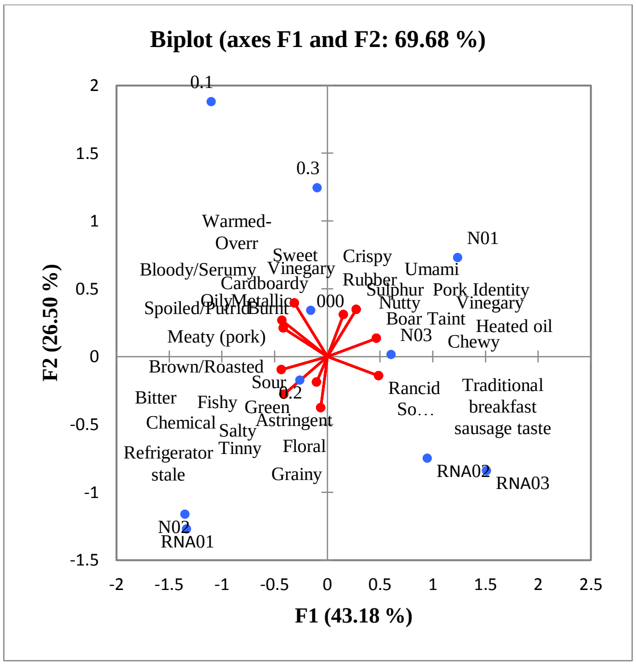
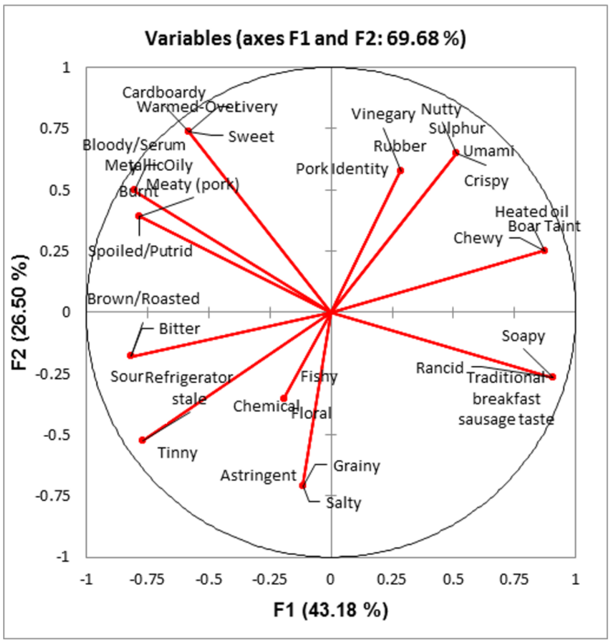


Figure 7.1: Process of recruitment, training and sesnory analysis of panellists

Figure 7.2: PCA of attributes generated (n=35) from day 2





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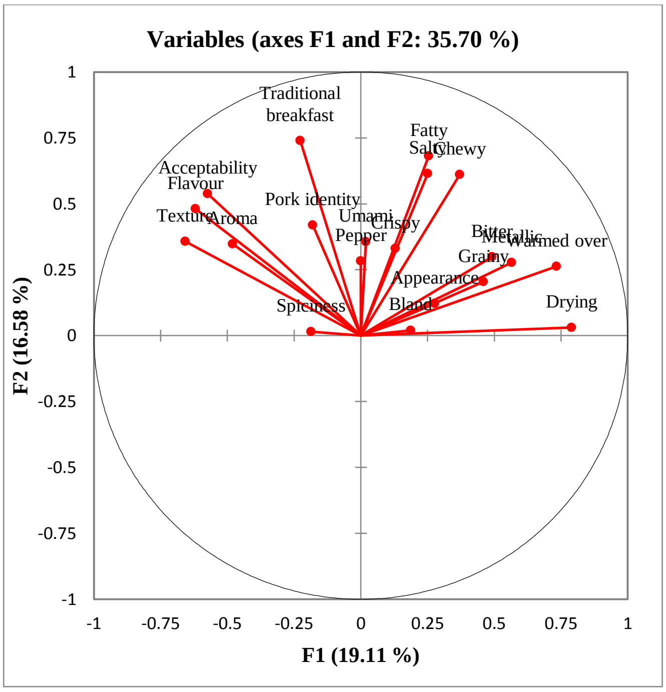
The fourth session involved training the panel on the scaling method. The references generated by the expert panel were introduced. The panellists familiarised themselves with the terms they generated and the references. The panel completed some line scaling exercises. Anchors were used to aid the panellist's decision and to reinforce the perceived intensity of the attributes to the panellists.

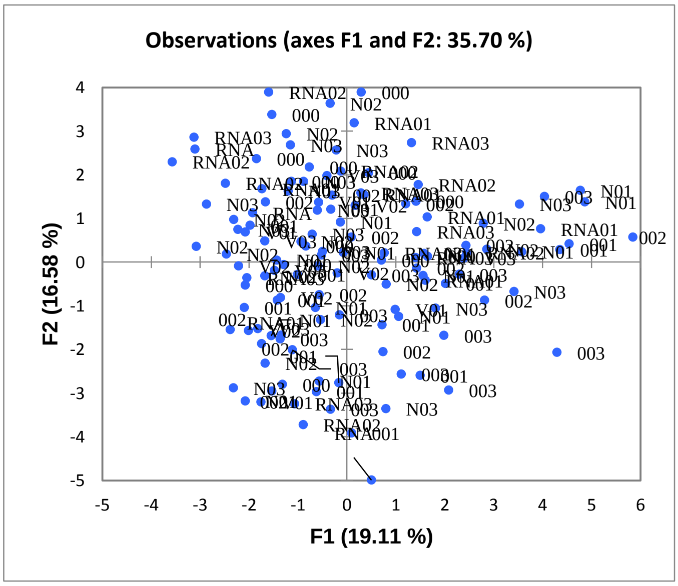
The fifth session involved using a 15cm scale. The anchors and the corresponding lexicons were used as previously developed by the expert panel. A representative sample set was tasted and a panel discussion followed. The list was again modified. The panellists discussed the anchors and developed new ones they felt explained the attribute with greater clarity.

During the sixth session, the panellists were asked to identify any reference or term they were not completely satisfied with or had difficulty with understanding. Umami, traditional sausage and pork identity proved challenging for this panellist, but this issue was resolved by the panel leader and through group discussion. The new references developed by the panellists were also used to help clarify the differences between attributes to the panellist. PCA was performed again and it was agreed from panel consensus that traditional sausage and pork identity would be two separate attributes due to the extra ingredients added to sausages. According to Fig 7.3, traditional breakfast sausage and pork identity were correlated together as expected. The samples associated with these meaty attributes included the samples containing salt and 0.3% MSG (N03), the control sample (C) and the sample containing NaCl and 0.2% MSG (N02). The control was expected to have a greater perception of meatiness, as high salt content has been proven to enhance the tastes of amino acids and meat flavour (Ugawa, Konosu, & Kurihara, 1992). Salty and fatty attributes were correlated together. Spiciness and bland were not connected, this indicated the good panellist performance. Metallic, warmed-over and drying were also associated together. This was also a good indication of panellist performance.

In the seventh session, the final attribute and lexicon list was presented to the panellists (Table 7.4). The panellists were asked to again familiarise themselves with the attributes and lexicons and indicate any difficulty they had in understanding the list. PCA was again carried out as can be seen from Fig 7.4.

Figure 7.3. PCA illustrating attributes generated on training day 6





000: Control, RNa = Reduced Sodium Salt, N: NaCl, MSG = Monosodium Glutamate

Table 7.4: Final list of descriptors and definitions (n=15) decided by the panel on day 7

Bitter	An unpleasant, dry taste and after taste, like tonic water	0.05% caffeine in water (2.0) 0.05% caffine in water (5.0)
Bland	Lacking flavour, not tasty (cardboard like flavour)	White pasta overcooked, drained and the water retained and pasta disposed of
Chewy	A product that takes a long time to chew – hard to break down	Maynards Wine gum (12)
Crispy	On first bite – crunch (in teeth) and a puncture to the sausage skin	Ready salted walkers crisps (15)
Drying	A drying sensation in your mouth after swallowing	Barrys tea bag soaked in boiling water for five minutes tea bag removed and cooled,
Fatty/Oily	Cooked animal fat smell, oil on your fingers, greasy, moist on your lips	Pork fat cooked to 72 degrees Celsius
Grainy	Consistency not uniform – texture is like white/black pudding / oaty texture	Rolled oats cooked in boiling water for 3 minutes
Metallic	Astringent, tropical, tinned foods. Old coins in your mouth sensation (after taste)	Pure pineapple juce dissolved in water (50:50) (6) Pure Pineapple juice (12)
Pepper	White pepper smell and taste (heating sensation)	Saxo white pepper 0.05% dissolved in water
Pork Identity	Sweet organ smell, like cooked pork chop smell. More dry/stringy/bland than other meats	Pork minced meat, cooked
Salty	Taste and after taste of salt water (NaCl)	0.1% salt in water (5) 0.2% salt in water (10) 0.5% salt in water (15)
Spiciness	Heat chilli like feeling; the sensation in your mouth after a mild curry, turmeric/cumin flavour	Schwartz Thai 7 spice seasoning 0.10% in water (4) Schwartz Thai 7 spice seasoning 0.35% in water (10) Schwartz Thai 7 spice seasoning 0.35% in water 0.50% (15)
Traditional Sausage	Fleshy taste, pork identity, savoury, greasy taste, that is grainy	Denny's cooked sausage cooked internal temperature of 72 degrees Celsius
Umami	Aromat, broathy, soup like, stock cube artificial smell and taste	0.038% Umami dissolved in water (10)
Warmed-Over	Dried out reheated meat smell	Pork mincemeat cooked and left overnight in the chiller and reheated in the microwave

Table 7.2: Screening questionnaire developed from panellists to assess their health status, eating habits, descriptive ability

Health Status	Eating Habits
Habits (Yes/No Response) • Do you smoke cigarettes? • Do you uses e-cigarettes? **Oral Health (Yes/No Response)** • Do you wear dentures? • Do you have difficulties swallowing? • Do you get frequent sore throat? • Do you have frequent mouth infections/ mouth ulcers/ thrush? **Eyesight (Yes/No Response)** • Do you wear tinted/light sensitive glasses? • Do you suffer from colour blindness? **Diseases (Yes/No Response)** Do you suffer from any of the following? • Asthma • Bronchitis • Coeliac Disease • Digestive Complaints • Eczema • Frequent head colds/flu • Frequent nasal infections • Hay fever • Heat complaints • High/low blood pressure • Kidney complaints • Liver complaints • Migraines / frequent headaches • Sinus problems • Anaphylactic reactions • Allergies • Diabetes • Are you taking any medications? • Are you on a restricted or a special diet	**Food Neophobia (Yes/No Response)** • I am constantly sampling new and different foods? • I do not trust new foods • I like foods from different countries • At dinner parties I will try new foods • I am afraid to try foods I have never eaten before • I am very particular about foods I eat • I like to try new restaurants **Food Involvement (Yes/No Response)** • I think about food a lot each day • Cooking is fun • Talking about food is something I like to do • Food choices are very important to me • When I travel I like to try new food **Descriptive ability (Open Ended Response)** • Imaging tasting a chocolate digestive biscuit and a marshmallow, please describe the main differences you would expect. **Declaration (Yes/No Response)** • Do you object to tasting processed meat? • Are you available to attend panel sessions on the proposed dates and times? • Are you willing not to wear perfume or use other heavily scented body lotions / soaps and shower gels on the days of training and testing? • Are you willing to refrain from eating food, drinking coffee and chewing gum 1 hr. prior to training and testing? • I hereby certify that the information I have given in this questionnaire is correct to the best of my knowledge

7.2.3.2.1 Triangle Test

A Triangle Test was performed on panellists using two flavoured sausages; one pork and leak and one pork sweet chili and mango. One non flavoured sausage was also analysed according to methods described in ISO, 4120 (2017). Panellists were presented with the three samples on a polystyrene plate that was randomly coded. Panellists were instructed to examine the sample by smelling in two short sniffs, to swirl the sample in their mouths for 3sec. and then swallow. The procedure was repeated with the other two samples. Panellists were instructed to select the odd sample. Panellists either passed or failed this test.

7.2.3.2.2 Duo Trio Test

A Duo-Trio Test was performed on panellists using one reference sample and two coded samples according to ISO 10399 (2010). Panellists were presented with the three samples (as mentioned previously in the triangle test) on a coded polystyrene plate. Panellists were instructed to examine the reference sample by smelling in two short sniffs, to swirl the sample in their mouths for 3sec and the swallow. The procedure was repeated with the other two samples. Panellists were instructed to select the same sample as the reference sample. Panellists either passed or failed.

7.2.3.2.3 Basic Taste Test

The basic tastes: sweet, sour, bitter, salty and umami were prepared using a sugar, citric acid, caffeine, salt and msg in a solution of water. Panellists were given the coded samples, then asked to match each sample to the basic taste. Panellists either passed or failed.

7.2.3.2.3 Taste Intensity

Taste intensity was used to encourage panellists to discriminate between concentrations of tastes. Panellists were given three coded samples, each with different concentrations of sugar, salt, lemon juice, caffeine and umami. According to the standards outlined in ISO 3972, (2011).

7.2.3.2.4 Odour Recognition Test

Odour Recognition testing was used to test olfactory ability. This involved identifying the foloowing aromas; vanilla, almond, vinegar and mint. Each odour was placed in a sealed test tube. Panellists were instructed to shake the tube before opening and smelling the substance. Panellists were then asked to identify the aromas. The panellists were rejected if they scores less than 60% on triangle tests and less than 75% on duo trio tests according to the methods of (Meilgaard, Civille, & Carr, 2007). The test was carried out in accordance with ISO, 5496 (2006).

7.2.3.3 Training of Panellists for QDA

Eight panellists ranging in age from 22 to 41 participated in the study. They were selected based on certain criteria. An outline of the screening questionnaire is presented in Table 2.

The panellists were required to sign a declaration stating that they regularly consume breakfast sausages, they do not have MSG allergies, and they not have any heart conditions. Panellists who passed the basic screening tests were recruited for the panel and monitored over time. Eight panellists were trained panellists according to QDA method O'Sullivan, Byrne and Martens (2002). Panellists were trained for a total of 7 sessions (total of 21 hours). The panellists were trained in attribute generation, lexicon generation and anchor generation according to ISO 8586 (2014). Their ability to identify pork meat attributes were assessed. Panellists were exposed to a variety of sausages, including samples to be evaluated as well as commercial brands, which reflected the main sensory variation in the profiling samples. Initially, they were asked to evaluate sensory differences among samples and make a list of the descriptors for these differences. They considered aroma, flavour, mouthfeel and aftertaste. Panellists were provided with lexicons as recommended by the expert panel. Panellists were asked to indicate whether each compound was related to each descriptor in the sausages. During the process of defining standards and preliminary evaluation of the samples, the initial list of descriptors was modified. A final list of lexicons used can be seen in Table 3. Panellists developed standards for each of the attributes. After further exposure to the products and more familiarity with standards panellists arrived at a consensus for the descriptors and the type of standards to use. Development of lexicons involved familiarising the panellists with different flavour attributes using references from AMSA (1995). The descriptors selected to be used in the flavour lexicon was determined by panel consensus. Random presentation with a 3-digit blinding codes were used. Panellist performance was measured throughout the study using PCA in accordance with IS0 11132 (2012). Panellists were considered trained when they could distinguish the replicate samples and their results agreed with the other panellists. Where panellists were having difficulty identifying an attribute the references and lexicons were used to encourage determining the attribute correctly. Panellists were trained on how to use the 15cm line scale. Anchors used ‘non-detectable’ to ‘intense’. After training the panellists were presented with the sausage samples. Nine samples were used for evaluation, along with 1 commercial sample.

7.2.3.4 Lexicon Generation by an Expert Panel

Prior to vocabulary development with the panel, an expert preliminary assessment of the sausage samples was used to characterise sensory samples and possible lexicons was carried out as per the methods of O’Sullivan, Byrne and Martens (2002).. Highly trained panellists, trained in QDA were used. The panel had extensive experience in evaluating sausages. The trained panellists evaluated the sausages to determine flavour and aroma attributes in each sample. The panellists discussed the flavour attributes found in each sample. Once all panellists came to a consensus about the attributes and intensities a discussion of the specific references that would represent each attribute took place. A previous pork lexicon developed by Chu (2015) was utilised to help the panel to create and omit sensory descriptors. A list of lexicons were also generated using this panel. These references were used for the training of the panel.

7.2.3.5 Lexicon Development

The panel were presented with various types of breakfast sausages. They included reduced salt, reduced fat, flavoured and commercial sausages. They were encouraged to describe the various attributes they felt were present in the samples. Panellists discussed the sample attributes and references. The individual terms were collected and a draft lexicon was established. Attributes were grouped according to types, similarities and categories. The panellists were exposed to attribute references previously described by the expert panel. The panellists and panel leader refined the attribute list and included definitions for each attribute. Terms were removed through discussion. Each generated lexicon was validated using a pair of samples. The lexicon criteria involved showing clear discrimination between the two samples. This process was carried out in accordance with (ISO 5492, 2009).

7.2.3.6 Sensory Evaluation

Sensory Evaluation took place in the sensory booths in UCC. The booths conform to the ISO standards (ISO 8589, 2014). The descriptors were selected from panel discussion as the most appropriate and reflected the main variation in the samples profiled. The samples were cooked to an internal temperature of 73°C and served as 30g portions, coded in randomised order and presented simultaneously to assessors (Stone, Bleibaum, & Thomas, 2012) with separate sessions undertaken for duplicates.

The samples were presented to the consumers on white polystyrene plates. The panellists were asked to rinse their mouths with water or have some unsalted cracker (Carrs table water biscuits) in-between each sample in accordance with the methods of Tobin et al. (2012a). Judges recorded their responses on a 15cm intensity line scale. Standards were available for comparison to samples. For aroma evaluation, judges smelled the samples in 2 short sniffs. Judges were instructed to swallow the samples and rinse their mouths with water in between samples.

7.3. Statistical Analysis

The panellist's performance was monitored at all times in accordance with (ISO 11132, 2012). Panel analysis was monitored using XLStat Panel Analysis function. A significant effect on product vs. session and assessor vs. session was observed. The following formulation was utilised: Y = P+J+S+P*J+P*S+J*S. A significance level of 5% was used and the random effects featured assessor and session (Theron, Muller, Van Der Rijst, Cronje, Le Roux, & Joubert, 2014). A PCA plot was carried out to assess whether the assessors agreed or disagreed for all descriptors. The relationship between the descriptors was analysed using MFA (multiple factor analysis).

An ANOVA was performed for each assessor separately and for each of the descriptors in order to check whether there was a product effect or not, to verify for each assessor if they were able to distinguish the products using the available descriptors. This was used to monitor panel performance. Atypical assessors were identified using the measure for each products of the Euclidean distance of each assessor to an average for all the descriptors. To check if there was a session effect a Wilcoxon signed ranked test was carried out on all products descriptors by descriptor. The assessors were then classified using GPA (Generalised Procristear Analysis).

7.4 Results and discussion

7.4.1 Training

Panellist training protocol followed the methods of O'Sullivan, (2017ab). On the first day of training, panellists were asked to generate attributes that they felt described the sensory characteristics of the sausage samples. They were also presented with the list of terms generated by the expert panel to aid with term generation. The purpose of this session was to introduce panellists to the samples and to familiarise them with descriptor usage. In total, 76 attributes were generated. Efficient sensory profiling requires the reduction of the number of terms to about 10 to 20 attributes (Vannier, Brun, & Feinberg, 1999). The choice of terms was based on a consensus discussion between panellists. Therefore, through panel discussion, descriptive sensory terms were removed or amalgamated after each session based on selection criteria, representative sample and reference assessment, panel discussions, panel term grouping suggestions and interpretation of PCA. Standardised PCA plots using the correlation matrix are commonly used in sensory analysis to display the relationships between attributes, as well as between individual samples. The PCA loadings plot (Fig 7.2) displays the positioning of, and the association between, positive and negative sausage attributes. PCA plots can also be used to determine if certain attributes are redundant and may be reduced to a simplified set of terms to prevent different attributes from being used to describe identical sensory characteristics (Tormod, Brockhoff, & Tomic, 2011). The terms were selected based on the following selection criteria; 1) Terms must have relevance to the product, 2) discriminate clearly between samples, 3) be non-redundant, and 4) have cognitive clarity to the assessors according to the previously stated methods of (Byrne, O'Sullivan, Dijksterhuis, Bredie, & Martens, 2001). A total of 40 attributes were removed, for example, the attributes 'earthy', 'soil like' and 'green' were considered to be non-discriminative.

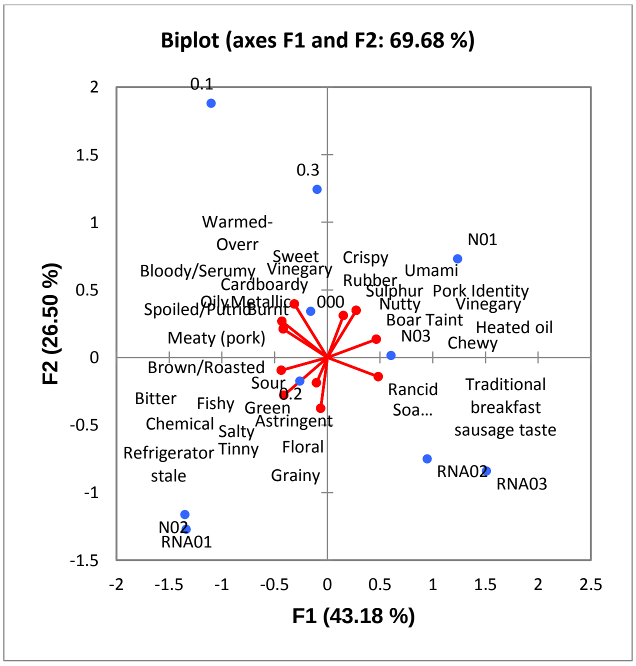
In the second day of training the reduced list of 35 terms, outlined in Table 7.3 were used. A similar evaluation to the first session was performed. PCA was carried out on the employed terms (Fig 7.2). The first principal component (PC1) explains 43.18% of the total variance and the second (PC2) explains 26.50% of variance. From Fig 7.2 the association between attributes and their samples can be seen. The cooked attributes such as brown and roasted were grouped, so too were off - flavours such as green, sour and refrigerator stale. Another 'off - flavour' grouping featured bloody, serumy, metallic, oily, burnt, spoiled and putrid. The cooked attributes were associated together and included terms such as cardboard, warmed over and livery. These attributes were negatively correlated with heated oil, boar taint and chewy. The attributes fishy, chemical and floral were not well correlated with the samples and were omitted. The attributes arising from flavour interactions relating to cooking, such as crispy; heated oil, burnt, warmed - over, meaty cardboard and those variations in sausage samples such as soapy, salty, traditional breakfast sausage flavour and bitter are presented in PC1. Thus, terms in PC1 described variation in the interactions between cooking volatiles and PC2 highlighted variation in samples which were both positive and negative for flavours. The control sample was correlated with cardboard, warmed-over and livery and sweet attributes. After this session 13 attributes were removed from the vocabulary as they were not considered to fulfil the selection criteria.

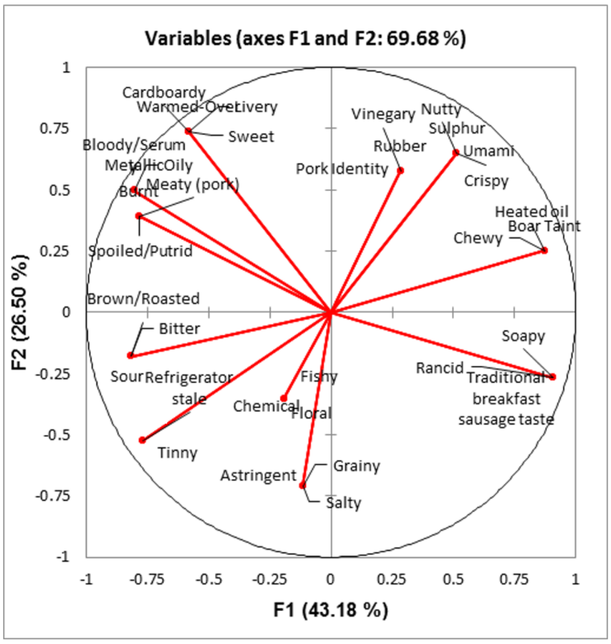
In the third session, the 22 remaining attributes were analysed in a similar way as session two. PCA was performed and 7 attributes were omitted. Panellist's performance improved as the sessions increased.

Table 7.3: List of Descriptors and Definitions (n= 35) decided by the Panel on day 2

Descriptor	Definition
Warmed-Over	Dried our reheated meat smell, unpleasant chemical flavour
Sulphur	Rotten eggs/striking a match smell, unpleasant chemical flavour
Rubber	Overheated tyre, the smell of an eraser, unpleasant chemical flavour
Green	Earthy, herby taste, E.g. Spinach, cabbage taste, unpleasant chemical flavour
Rancid	Gone off fat or a dairy product. More bitter than putrid, unpleasant chemical flavour
Fishy	Distinct oily fish smell and taste, pungent negative flavour
Astringent	A drying pinching on the tongue – with a slight metallic taste, negative mouth feel and flavour
Boar Taint	An unpleasant smell associated with moth balls, chemical flavour
Bloody/Serumy	Metallic, slightly sweet, blood like smell, warming negative flavour
Brown/Roasted	Pork scratching's, cooked fatty smell, cooked animal skin, negative, warming
Burnt	Overcooked caramel/blackened toast, warming negative flavour
Cardboardy	Faint woody smell – like smelling a cardboard box, negative, warming flavour
Nutty	Woody/toasted/earthy/roasted after taste with a fatty/oily texture, negative warming flavour
Pork Identity	Sweet organ smell, like cooked pork chop smell. More dry/stringy/bland than other meats, traditional positive flavour
Refrigerator stale	Undesirable rubbish bin smell. A mouldy, musty, sweet smell like silage. The loss of own taste absorbance's of smells from the fridge, negative traditional flavour
Soapy	Chemical smell, sweet, clean, non – edible: the smell of clean hands after washing them in soap, pungent negative flavour
Chemical	An unpleasant metallic bitter off taste, a warning signal, Smells like petroleum based products, pungent negative flavour
Floral	Fresh summer burst: A rose like sweet smell, pungent negative flavour
Heated oil	Fast food shop smell, greasy, ready salted crisps smell and taste, warming positive flavour
Metallic	Astringent, tropical, tinned foods. Old penny's in your mouth sensation, chemical negative flavour
Sour	Lemmon like taste, gone off milk. A pinch/tingle in your jaw, basic negative flavour
Spoiled/Putrid	Vomit, repulsive, foul smell. Similar to potato decay smell, pungent negative flavour
Sweet	Feeling perceived on the front of the tongue – A Sugar, syrup, hard boiled sweet flavour, basic positive flavour
Umami	Aromat, breathy, soup like, stock cube artificial smell and taste, basic positive flavour
Vinegary	Chips, salt and vinegar crisps. Both the smell and taste associated with vinegar, chemical negative flavour
Tinny	Metallic, tin can smell, negative flavour
Traditional breakfast sausage taste	Peppery, fleshy taste, pork identity, savoury, greasy taste, that is grainy, traditional positive flavour
Salty	Taste and after taste of salt water (NaCl), basic positive flavour
Grainy	Consistency not uniform – texture is like white/black pudding/ oaty texture, positive mouth feel
Chewy	A product that takes a long time to chew – hard to break down, positive mouth feel and texture
Oily	Oil on your fingers, greasy, moist on your lips, positive mouth feel and texture
Bitter	An unpleasant, dry taste and after taste like tonic water, negative basic flavour
Meaty (pork)	Strongly flavoured meat taste. Like pork chop smell, traditional, positive
Livery	Organ, haggis, metallic like negative flavour and smell
Crispy	On first bite – crunch (in teeth) and a puncture to the sausage skin

Figure 7.2: PCA of attributes generated (n=35) from day 2





000: Control, RNa: Reduced Sodium Salt, N: NaCl

The fourth session involved training the panel on the scaling method. The references generated by the expert panel were introduced. The panellists familiarised themselves with the terms they generated and the references. The panel completed some line scaling exercises. Anchors were used to aid the panellist's decision and to reinforce the perceived intensity of the attributes to the panellists.

The fifth session involved using a 15cm scale. The anchors and the corresponding lexicons were used as previously developed by the expert panel. A representative sample set was tasted and a panel discussion followed. The list was again modified. The panellists discussed the anchors and developed new ones they felt explained the attribute with greater clarity.

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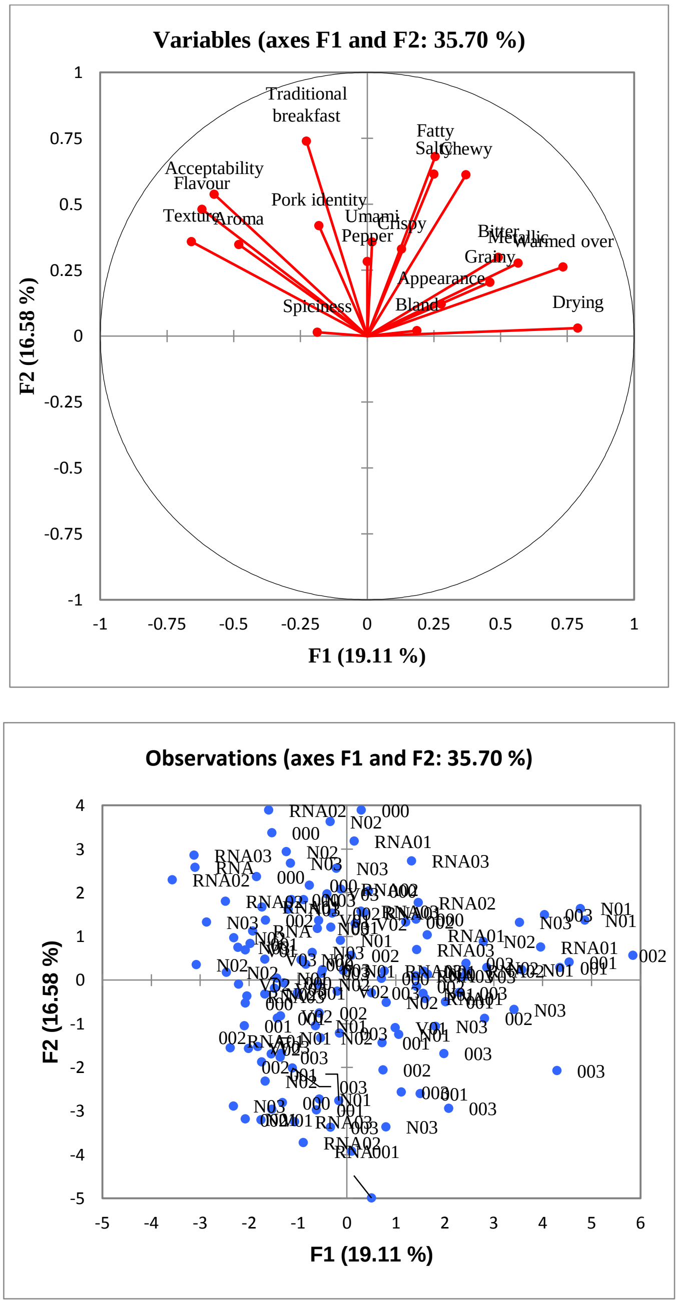
In the seventh session, the final attribute and lexicon list was presented to the panellists (Table 7.4). The panellists were asked to again familiarise themselves with the attributes and lexicons and indicate any difficulty they had in understanding the list. Agreed on the list. PCA was again carried out as can be seen from Fig 7.4.

Figure 7.3. PCA illustrating attributes generated on training day 6



000: Control, RNa: Reduced Sodium Salt, N: NaCl, MSG = Monosodium Glutamate

Table 7.4: Final list of descriptors and definitions (n=15) decided by the panel on day 7

Attribute	Descriptor	Defination
Bitter	An unpleasant, dry taste and after taste, like tonic water	0.05% caffeine in water (2.0) 0.05% caffine in water (5.0)
Bland	Lacking flavour, not tasty (cardboard like flavour)	White pasta overcooked, drained and the water retained and pasta disposed of
Chewy	A product that takes a long time to chew – hard to break down	Maynards Wine gum (12)
Crispy	On first bite – crunch (in teeth) and a puncture to the sausage skin	Ready salted Walkers crisps (15)
Drying	A drying sensation in your mouth after swallowing	Barrys tea bag soaked in boiling water for five minutes, tea bag removed and cooled,
Fatty/Oily	Cooked animal fat smell, oil on your fingers, greasy, moist on your lips	Pork fat cooked to 72 degrees Celsius
Grainy	Consistency not uniform – texture is like white/black pudding / oaty texture	Rolled oats cooked in boiling water for 3 minutes
Metallic	Astringent, tropical, tinned foods. Old coins in your mouth sensation (after taste)	Pure pineapple juce dissolved in water (50:50) (6) Pure Pineapple juice (12)
Pepper	White pepper smell and taste (heating sensation)	Saxo white pepper 0.05% dissolved in water
Pork Identity	Sweet organ smell, like cooked pork chop smell. More dry/stringy/bland than other meats	Pork minced meat, cooked
Salty	Taste and after taste of salt water (NaCl)	0.1% salt in water (5) 0.2% salt in water (10) 0.5% salt in water (15)
Spiciness	Heat chilli like feeling; the sensation in your mouth after a mild curry, turmeric/cumin flavour	Schwartz Thai 7 spice seasoning 0.10% in water (4) Schwartz Thai 7 spice seasoning 0.35% in water (10) Schwartz Thai 7 spice seasoning 0.35% in water 0.50% (15)
Traditional Sausage	Fleshy taste, pork identity, savoury, greasy taste, that is grainy	Denny's cooked sausage cooked internal temperature of 72 degrees Celsius
Umami	Aromat, broathy, soup like, stock cube artificial smell and taste	0.038% Umami dissolved in water (10)
Warmed-Over	Dried out reheated meat smell	Pork mincemeat cooked and left overnight in the chiller and reheated in the microwave

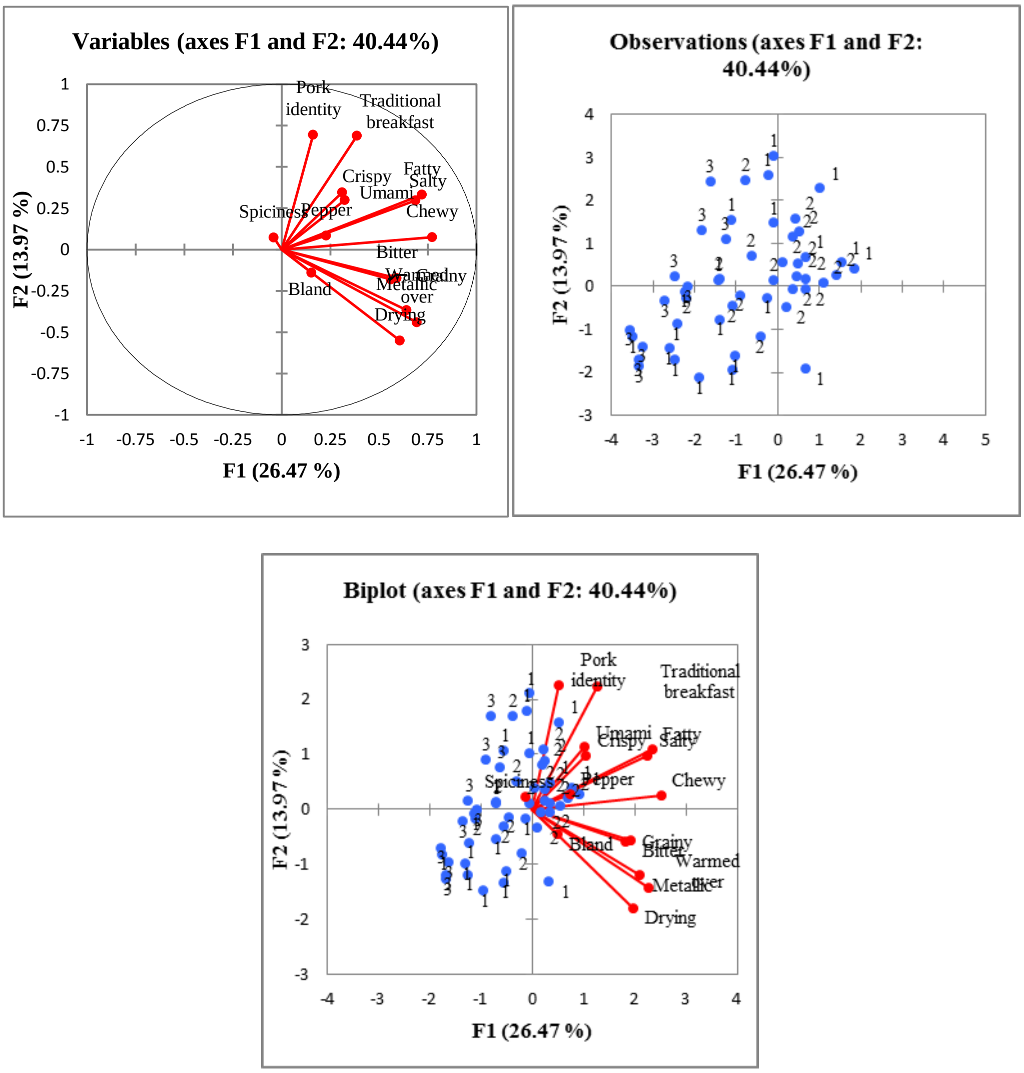


Fig 7.4: PCA, observations and biplot illustrating data generated from training day 7

7.4.2 The Sensory Wheel

Based on the frequency of quotation, 10 taste attributes and 5 texture attributes were selected from the list of descriptive terms generated by the panel during the training sessions. Sixty defining attributes were also inserted. Sixty of these descriptors were subjected to descriptive analysis while the remaining 16 did not occur frequently. The terms were assembled to form a 3-tiered wheel (Fig 7.6). The descriptors used for this wheel are limited to the 10 samples that were analysed examining the effects MSG has on the flavour amplification of fat and salt reduced sausages. The first generic sensory wheel developed for low fat and salt breakfast sausages in this study can be used as a communication tool for researchers and new product development in industry. It can also be utilised for comparing and monitoring product quality and consistency as well as for the development of new low fat and salt breakfast sausages. It can be expected that depending on the sausage type slight modifications may have to be used. An improvement and refinement to attributes can be carried out as deemed appropriate over time.

Figure. 7.6: Sausage sensory wheel comprising of terms that describe the sensory attributes of flavour enhanced low fat and low salt breakfast sausages

Three tier sensory wheel encompassing taste and texture attributes and the attributes (n=15) generated by the panellists

7.4.3 Sensory Evaluation

The results obtained from the sensory evaluation of the products can be seen in Tables 7.5 and 7.6. Table 7.5 outlines sample attribute differences. From this table, the attributes of 'spiciness' and 'saltiness' were deemed the most significant contributing attributes in determining panellist judgements between samples. This result was expected as these samples varied in salt content. MSG is a flavour enhancer (Chun et al., 2014; Mustafa, Saleem, Hameed, 2015), thus it would be expected that the samples containing 0.01, 0.02 and 0.03% MSG with salt would be perceived as being more salty than those samples containing only salt. Sausages containing 0.2% MSG (002), reduced sodium sea salt with 0.1% MSG (NaR01), NaCl and 0.2% MSG (N02) and NaCl and 0.3% MSG (N03) were all considered to have the same degree of saltiness as the control sample, which had the highest salt content. Thus, salt perception was enhanced by utilising MSG in the formulation. Other studies reported similar results, whereby, as MSG increased in the formulation, so too did the sensory perception of saltiness (Prescott, 2001; Morris, Koliandris, Wolf, Hort, & Taylor, 2009).

It is interesting to note that sausages containing no salt or reduced sodium salt, but containing 0.2% MSG, was equal to the panellist's salt perception of control samples. The panellists noted the reduced saltiness perception in sausages which contained reduced sodium salt (NaR02 & NaR03) and those containing NaCl and the lowest amount of MSG (0.1%). Thus, 0.2 and 0.3% levels of MSG were successful in enhancing saltiness perception. The control sample featured the lowest rating for spiciness as perceived by the trained panellists. The high salt content may mask higher spiciness perception. Greater spiciness was associated with sausages containing reduced sodium salt, NaCl and 0.1% MSG (N01) and NaCl and 0.03% MSG (N03). Four sausage samples were determined as being significantly similar to control samples. The first three samples featured no salt or reduced sodium salt and contained only MSG. The last sample listed featured NaCl and 0.2% MSG (001, 002, 003 and N02). Thus, it can be concluded that MSG may dull the perception of spiciness, by enhancing other attributes such as saltiness in sausage-type products.

The flavour wheel (Fig 7.6) was generated using XlStat. The flavour wheel was used as a guide for panellists while carrying out product sensory analysis. The wheel incorporates the taste aroma and textural parameters panellists associated with sausage samples. Panellists were encouraged to read the wheel from the centre outwards. The fifteen finalised attributes are present in tier two, with the associated features on tier three. Table 6 outlines the differences in sausage samples compared to the control. No attribute difference was observed by panellists for sausages containing NaCl and 0.2% MSG (N02) and the control sample. Consequently, this sample may be considered the 'gold standard' formula in which the trained panellists were not able to identify any differing attributes between the sample and the control. This formulation could be useful for the replacement of traditional formulas with a low-fat, low-salt sausage formulation. Sausages containing only MSG and no salt or reduced sodium salt samples (001, 002 & 003) all varied from the control sample owing to their association with saltiness. Sausages containing reduced sodium salt (NaR01, NaR02 & NaR03) all varied from the control sample due to their affiliation with the attribute of spiciness, as did those containing NaCl and 0.3% MSG (N03). Sausages containing reduced sodium salt and 0.2% and 0.3% MSG and those containing NaCl and 0.01% MSG (samples NaR02, NaR03 and NaR01) all differed from the control sample owing to saltiness and spiciness attributes associated with them.

Table 7.5: Difference between attributes in the samples

Sample	Bitter	Bland	Chewy	Crispy	Drying	Fatty	Grainy	Metallic	Pepper	Pork identity	Salty	Spiciness	Traditional breakfast	Umami	Warmed over
000*	2.192 ^{a}	2.777 ^{a}	4.038 ^{a}	4.392 ^{a}	2.108 ^{a}	5.277 ^{a}	3.262 ^{a}	2.123 ^{a}	1.946 ^{a}	4.700 ^{a}	5.231 ^{b}	1.485 ^{a}	3.315 ^{a}	2.069 ^{a}	1.138 ^{a}
001	0.777 ^{a}	5.515 ^{a}	3.638 ^{a}	3.669 ^{a}	3.454 ^{a}	3.308 ^{a}	4.354 ^{a}	1.348 ^{a}	1.392 ^{a}	3.838 ^{a}	2.223 ^{a}	2.177 ^{ab}	2.123 ^{a}	1.923 ^{a}	2.038 ^{a}
002	1.623 ^{a}	4.492 ^{a}	4.415 ^{a}	4.192 ^{a}	2.792 ^{a}	3.777 ^{a}	4.023 ^{a}	2.169 ^{a}	1.646 ^{a}	4.069 ^{a}	3.023 ^{ab}	2.177 ^{ab}	2.038 ^{a}	2.700 ^{a}	1.662 ^{a}
003	0.723 ^{a}	6.015 ^{a}	4.185 ^{a}	3.108 ^{a}	4.331 ^{a}	3.269 ^{a}	4.238 ^{a}	1.800 ^{a}	1.485 ^{a}	3.831 ^{a}	2.115 ^{a}	2.269 ^{ab}	1.746 ^{a}	2.592 ^{a}	1.585 ^{a}
RNa01	1.900 ^{a}	2.708 ^{a}	4.277 ^{a}	3.154 ^{a}	2.123 ^{a}	4.377 ^{a}	3.977 ^{a}	2.546 ^{a}	2.031 ^{a}	3.362 ^{a}	3.362 ^{ab}	3.354 ^{b}	2.577 ^{a}	2.577 ^{a}	1.262 ^{a}
RNa02	0.900 ^{a}	5.715 ^{a}	4.523 ^{a}	3.308 ^{a}	2.692 ^{a}	4.923 ^{a}	3.815 ^{a}	1.108 ^{a}	2.131 ^{a}	4.554 ^{a}	2.485 ^{a}	3.438 ^{b}	3.123 ^{a}	2.485 ^{a}	1.062 ^{a}
RNa03	2.031 ^{a}	2.592 ^{a}	3.908 ^{a}	4.169 ^{a}	2.831 ^{a}	4.662 ^{a}	4.777 ^{a}	1.869 ^{a}	2.031 ^{a}	4.115 ^{a}	2.823 ^{a}	3.685 ^{b}	2.777 ^{a}	1.992 ^{a}	1.331 ^{a}
N01	2.077 ^{a}	4.477 ^{a}	4.708 ^{a}	5.200 ^{a}	3.562 ^{a}	4.131 ^{a}	4.269 ^{a}	2.392 ^{a}	1.538 ^{a}	3.254 ^{a}	2.700 ^{a}	3.477 ^{b}	1.715 ^{a}	2.215 ^{a}	1.392 ^{a}
N02	1.631 ^{a}	2.785 ^{a}	3.808 ^{a}	3.069 ^{a}	1.854 ^{a}	4.962 ^{a}	3.608 ^{a}	1.677 ^{a}	1.254 ^{a}	4.746 ^{a}	3.915 ^{ab}	2.831 ^{ab}	3.262 ^{a}	2.838 ^{a}	1.123 ^{a}
N03	2.162 ^{a}	2.300 ^{a}	4.631 ^{a}	3.469 ^{a}	3.146 ^{a}	4.777 ^{a}	3.446 ^{a}	1.454 ^{a}	1.600 ^{a}	4.446 ^{a}	4.508 ^{ab}	3.531 ^{b}	3.085 ^{a}	2.385 ^{a}	1.046 ^{a}
Pr > F	0.266	0.153	0.940	0.105	0.133	0.063	0.758	0.619	0.587	0.306	0.000	0.003	0.114	0.818	0.940
Significant	No	No	No	No	No	No	No	No	No	No	**Yes**	**Yes**	No	No	No

* = Control Sample

Table 7.6: Attribute differences between samples and control

Contrast	Bitter	Bland	Chewy	Crispy	Drying	Fatty	Grainy	Metallic	Peppery	Pork	Salty	Spicy	Traditional Sausage	Umami	Warmed Over
	Significant														
000* vs 001	No	No	No	No	No	No	No	No	No	No	**Yes**	No	No	No	No
000 vs 002	No	No	No	No	No	No	No	No	No	No	**Yes**	No	No	No	No
000* vs 003	No	No	No	No	No	Yes	No	No	No	No	**Yes**	No	No	No	No
000 vs RNa01	No	No	No	No	No	No	No	No	No	No	No	**Yes**	No	No	No
000 vs RNa02	No	No	No	No	No	No	No	No	No	No	**Yes**	**Yes**	No	No	No
000 vs RNa03	No	No	No	No	No	No	No	No	No	No	**Yes**	**Yes**	No	No	No
000 vs N01	No	No	No	No	No	No	No	No	No	No	**Yes**	**Yes**	No	No	No
000 vs N02	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
000 vs N03	No	No	No	No	No	No	No	No	No	No	No	**Yes**	No	No	No

* = Control Sample

7.4 Conclusion

The standardised lexicon generated in this study provides industry and research with a reference for evaluating the main sensory variation in reduced fat and salt breakfast sausages. A low-fat and low-salt pork breakfast sausage lexicon was successfully developed and validated by the trained panellists. Differences in attributes were established and differences were found between treatments. The flavour wheel proved to be a useful tool in organising attributes in a visually appealing way. The wheel served as a thought-provoking device when trying to characterise attribute differences. The following sausage attributes were deemed the most distinguishing features between low-fat and low-salt sausages; bitter, bland, chewy, crispy, drying, fatty, grainy, metallic, peppery, pork identity, salty, spicy, traditional sausage flavour, umami and warmed over. The product attributes of spicy and salty were the most distinguishing attributes defining low-fat and low-salt sausages from control samples. Sausages containing NaCl and 0.2% MSG was deemed to be the optimal formulation i.e., the sample most resembling the control sample. MSG may be used in conjunction with reduced salts to obtain the same 'saltiness' perception as traditional sausages which contain higher levels of salt. This sample may be used to replace traditional breakfast sausages with a low-fat and low-salt substitute. Additional research lexicon validation needs to be carried out using pork lexicons to ensure consistency within the pork meat industry. This would ensure better communication between researchers and industry regarding the flavour amplification possibilities by utilising MSG in pork sausages.

CHAPTER 8

Sensory profiling and external preference mapping of young- to middle-aged and the elderly consumer groups

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Abstract

The objectives of this study were to evaluate the flavour profile and acceptability of 10 sausage formulations varying in MSG, salt and fat levels using descriptive analysis and consumer acceptance tests; and to determine drivers for liking by applying external preference mapping and highlighting the relationship between descriptive attributes and hedonic judgements using partial least squares methodology. Sausage formulations (n=10) ranging in salt (0.0-2.5%), fat (15-30%) and MSG (0.0-0.3%) were investigated. Descriptive sensory profiles for sausage treatments were determined using a trained panel (n=10) and employing established sausage flavour lexicons. Sausages were evaluated for consumer acceptability by varying age groups (18-85 years old). Consumers (n=288) assessed sausage treatments in terms of preference. A preference map was generated utilising data obtained from the trained panel and the consumer panel. Sausage flavour preferences varied among different aged consumers. Consumers aged under 65 had a greater preference for sausages containing MSG at levels of 0.1, 0.2 and 0.3%. Consumers aged over 65 preferred control sausages and those containing reduced sodium salt and 0.1% MSG, whereas considering the greatest overall assessor acceptance, the sample containing NaCl and 0.1% MSG displayed the greatest acceptability for both the consumers and the trained panel. These significant relationships indicate that breakfast sausage acceptance is related to the amount of spiciness and saltiness in the sausages and it varies among consumers in specific age cohorts.

Key words: salt, fat, MSG, Sensory Analysis, Descriptive Analysis, Preference Mapping

8.1 Introduction

Consumers are the final step in the production chain. By ensuring their expectations are met, satisfaction in turn should lead to increases in product sales. Meat and meat products are important components of consumers daily or weekly shopping. They are an excellent source of protein, iron, zinc, niacin and vitamins (Brewer, 2012). However, products such as breakfast sausages are criticised for their high sodium and fat contents (Desmond, 2006). Some advances in reducing the sodium content in meat products have been studied, including; reduction of salt without salt replacement as well as use of other salts, for example KCl and $MgCl_2$ and $CaCl_2$ (Horita, Morgano, Celeghini, & Pollonio, 2011). Many studies have performed fat replacement trials on breakfast sausages using fructo-oligosaccherides, oat and wheat fibre and barley beta glucan (Cáceres, Garcıa, Toro, & Selgas, 2004; Huang et al., 2011; Morin et al., 2004). However, reduction and replacement of the two key flavour inducing ingredients – salt and fat in breakfast sausages may influence flavour perception of consumers, and in turn, decrease product palatability. Thus, there is a need to find alternative methods to allow for palatability to compensate for the lack of taste due to the replacement and reduction of fat and salt. Recent evidence suggests that Monosodium glutamate (MSG) has flavour-enhancing properties that may allow for a reduced level of fat and salt to be added to products by enhancing their flavour compounds (Mustafa, Saleem, Hameed, & Author, 2015). Umami is recognised as the fifth basic taste and is stimulated by the non-essential amino acid glutamic acid and aspartic acid and the 5 ‘ribonucleotides. MSG is a glutamic acid. Glutamic acid is a major constituent of food proteins (plant and animal). Additionally, free glutamic acid is present naturally in most foods, such as meat, poultry, seafood and vegetables (Ninomiya, 1998). Palatability promotes the selection, intake, absorption and digestion of foods. All five senses are involved in determining food palatability, with taste playing a major role. Umami compounds in simple aqueous solutions are not rated highly by sensory panellists as being pleasant. However, in food matrices, addition of umami substances may enhance sensory panellist ratings for overall flavour and preferences (Klee, & Tieman, 2018). Umami compounds that contain sodium salts may exhibit a separate slightly salty taste. This is obtained from the Na^+ cation. It has also been hypothesised that some proteins and fats may also contribute to umami tastes (Fuke & Ueda, 1996). In one salt replacement study employing fermented sausages, it was determined that replacing 50% and 75% NaCl and KCl, respectively, with MSG allowed for the production of fermented cooked sausages with good sensory acceptance and approximately 68% sodium reduction (dos Santos, Campagnol, Morgano, & Pollonio, 2014).

Taking the needs of consumers into account is vital in product design. In many circumstances, aesthetic properties are as vital as technical functions. The subjective measure of the requirements, the feelings, impressions, sensations or preferences that customers have must be quantified and modelled in advance. This is the foremost challenge in industrial design. Methods and tools need to be developed so that the subjectivity of human analysis can be captured and unified into the design process. Preference mapping aids those developing new products to understand the driving force behind consumer's preferences. It is commonly used to examine the relationships between descriptive sensory data and consumer preferences. Little research has been conducted into the consumer perception and acceptability of the flavour profiles of breakfast sausages. The developments of low-fat and low-salt sausages are typically classified as a more healthful option. However, it does produce another flavour profile. As breakfast sausages are a traditional meat product, various generations may have varying preferences for sausages due to formulation changes which have occurred over time. The objective of this study was to elucidate the flavour profile and acceptability of 10 breakfast sausage formulations employing varying fat, salt and MSG levels using descriptive analysis and consumer tests.

8.2 Materials and Methods

8.2.1 Sausage Preparation

Fresh boneless pork and pork back fat was purchased from local processors (Ballyburden Meats Ltd, Ballincollig, Cork, Ireland). The meat and fat were cut, weighed and placed into vacuum packs accordingly. They were stored in the freezer (-18°C). Prior to use, the meat and fat were thawed slightly at refrigerator temperature (4°C) before being minced through a 10mm plate (TALSABELL, Valencia, Spain). The ingredients were weighed according to formulations shown in Table 1. The pork, seasoning (0% sodium), salt, MSG, pea starch, reduced sodium salt and a third of the required water were fed into a bowel chopper and mixed at high speed for 45s. The required fat was then added to the bowel chopper and the mix was chopped for a further 45s at high speed. The remaining water was added and mixed for a further 30s at high speed. Finally, the pin head rusk was added for 30s at low speed. The sausage mix was then put into the casing filler and fed into collagen casings. The sausages were the sealed in vacuum pack bags and refrigerated overnight (4°C).

8.2.2 Cooking

Oven cooking was chosen as the method to cook sausages. Each sausage sample was wrapped in tin foil, labelled and dry cooked at 150°C in a Zanussi convection oven (C. Batassi, Conegliano, Italy) for 20min to an internal temperature of 73°C, as measured by a temperature probe (Testo 110, Lenzkirch. Germany).

Table 8.1: Sausage Formulation Table

%	C	RNa 0.1	RNa0.2	RNa 0.3	N 0.1	N 0.2	N 0.3	0.1	0.2	0.3
Pork	35	35	35	35	35	35	35	35	35	35
Fat	30	15	15	15	15	15	15	15	15	15
Pea	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
RNa	0	1	1	1	0	0	0	0	0	0
Rusk	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Seasoning	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
NaCl	2.5	0	0	0	1	1	1	0	0	0
Water	17.5	33.4	33.3	33.2	33.4	33.3	33.2	34.4	34.3	34.2
MSG	0	0.1	0.2	0.3	0.1	0.2	0.3	0.1	0.2	0.3

C: Control, RNa = Reduced Sodium Salt, N: NaCl

Table 8.2: Descriptors used for the sensory profiling of breakfast sausages

Descriptor	Definition	References
Bitter	An unpleasant, dry taste and after taste, like tonic water	0.08% caffeine in water
Bland	Lacking flavour, not tasty (cardboard like flavour)	Carrs Table Water Biscuits
Chewy	A product that takes a long time to chew – hard to break down	Chewits strawberry flavoured sweets
Crispy	On first bite – crunch (in teeth) and a puncture to the sausage skin	Denny sausage fried in vegetable oil
Drying	A drying sensation in your mouth after swallowing	Carrs Table Water Biscuits
Fatty/Oily	Cooked animal fat smell, oil on your fingers, greasy, moist on your lips	Pork fat cooked
Grainy	Consistency not uniform – texture is like white/black pudding / oat texture	Clonakilty black pudding
Metallic	Astringent, tropical, tinned foods. Old coins in your mouth sensation (after taste)	100% Pineapple juice
Pepper	White pepper smell and taste (heating sensation)	Saxo white pepper dissolved in water
Pork Identity	Sweet organ smell, like cooked pork chop smell. More dry/stringy/bland than other meats	Ground Pork cooked
Salty	Taste and after taste of salt water (NaCl)	Salt in water
Spiciness	Heat chilli like feeling; the sensation in your mouth after a mild curry, turmeric/cumin flavour	Chinese five spice seasoning Schwartz in water
Traditional sausage	Fleshy taste, pork identity, savoury, greasy taste, that is grainy	Denny sausages cooked
Umami	Aromat, broath like, soup like, stock cube artificial smell and taste	0.035% Knorr Aromat seasoning in water
Warmed-Over	Dried out reheated meat smell	80/20 Ground Pork, cooked, left chilled overnight and reheated

8.2.3 Sensory consumer testing

Sensory consumer testing was conducted in accordance with ISO standards. Sausages were cut into 4cm pieces for analysis. Each panellist received 10 samples in Styrofoam containers with lids and coded with random three-digit numbers. This was carried out to ensure sausages were maintained at the same temperature throughout evaluation. The presentation order of the samples was randomised to consider the effect of rank. Each panellist received 10 sausage samples at each session. Ten sausage samples were assessed, which included one control sample as shown in Table 8.1. The panellists evaluated the samples in duplicate. Assessors were provided with table water crackers and water to cleanse the palate between each sample. Sensory analysis was conducted in individual panel booths conforming to ISO standards.

8.2.3.1 Consumer evaluation

The consumer acceptability of the sausage samples was evaluated by a panel of untrained assessors (n=288). The ages ranged from 18-85 yrs. old. The younger consumers were recruited from the pool of staff and students at University College Cork through personal communication, advertisements and e-mail. The over sixty-five year old panellists were recruited from various active retirement groups around Cork City and County. Consumers filled out a consent form prior to participating in the sensory analysis. Three sessions were conducted over a span of three weeks and within one week of the descriptive analysis by the trained panel. Evaluation was conducted at the same time for every session at the sensory evaluation laboratory. Combined age group means for the attributes is outlined in Table 8.5. Consumer evaluation was conducted on two different age cohorts. Those aged below sixty-five and those aged sixty-five and over. Currently, 65 is defined as the elderly age. However there have been some suggestions to updating this age to those over 75 yrs. of age instead of the current 65 yrs. based on social, cultural and medical sciences (Orimo et al., 2006). For the purpose of this study, the elderly referred to those over the age of 65 yrs. old. They rated samples using a 9-point hedonic scale according to the methods of Young, Drake, Lopetcharat, & McDaniel, (2004), where 1=extremely dislike/low intensity and 9=extremely like/highintensity.

Table 8.3: Descriptive attribute means for the breakfast sausages

Sample	Bitter	Bland	Chewy	Crispy	Drying	Fatty	Grainy	Metallic	Pepper	Pork	Salty	Spicy	Traditional	Umami	Warmed over
C	0.900 ^{ab}	5.715 ^{ab}	4.523 ^{a}	3.308 ^{b}	2.692 ^{abc}	4.923 ^{ab}	3.815 ^{a}	1.108 ^{a}	4.554 abc	2.131 a	2.485 cd	3.438 ab	3.123 $_{a}$	2.485 $_{a}$	1.062 ^{a}
RNa01	2.031 ^{ab}	2.592 ^{bc}	3.908 ^{a}	4.169 ^{ab}	2.831 ^{abc}	4.662 $_{abc}$	4.777 ^{a}	1.869 ^{a}	2.031 a	4.115 abc	2.823 cd	3.685 ^{a}	2.777 ^{ab}	1.992 ^{a}	1.331 ^{a}
RNa02	2.192 ^{a}	2.777 ^{abc}	4.038 ^{a}	4.392 ^{ab}	2.108 ^{bc}	5.277 ^{a}	3.262 ^{a}	2.123 ^{a}	1.946 ^{a}	4.700 ^{ab}	5.231 ^{a}	1.485 ^{d}	3.315 ^{a}	2.069 ^{a}	1.138 ^{a}
RNa03	2.077 ^{ab}	4.477 ^{abc}	4.708 ^{a}	5.200 ^{a}	3.562 ^{ab}	4.131 $_{abc}$	4.269 ^{a}	2.392 ^{a}	1.538 ^{a}	3.254 ^{c}	2.700 ^{cd}	3.477 ^{ab}	1.715 ^{b}	2.215 ^{a}	1.392 ^{a}
N01	2.162 ^{ab}	2.300 ^{c}	4.631 ^{a}	3.469 ^{b}	3.146 ^{abc}	4.777 ^{ab}	3.446 ^{a}	1.454 ^{a}	1.600 ^{a}	4.446 ^{abc}	4.508 ^{ab}	3.531 ^{a}	3.085 ^{ab}	2.385 ^{a}	1.046 ^{a}
N02	1.623 ^{ab}	4.492 ^{abc}	4.415 ^{a}	4.192 ^{ab}	2.792 ^{abc}	3.777 ^{bc}	4.023 ^{a}	2.169 ^{a}	1.646 ^{a}	4.069 ^{abc}	3.023 ^{bcd}	2.177 ^{cd}	2.038 ^{ab}	2.700 ^{a}	1.662 ^{a}
N03	1.900 ^{ab}	2.708 ^{abc}	4.277 ^{a}	3.154 ^{b}	2.123 ^{bc}	4.377 $_{abc}$	3.977 ^{a}	2.546 ^{a}	2.031 ^{a}	3.362 ^{bc}	3.362 ^{bcd}	3.354 ^{abc}	2.577 ^{ab}	2.577 ^{a}	1.262 ^{a}
01	1.631 ^{ab}	2.785 ^{abc}	3.808 ^{a}	3.069 ^{b}	1.854 ^{c}	4.962 ^{ab}	3.608 ^{a}	1.677 ^{a}	1.254 ^{a}	4.746 ^{a}	3.915 ^{abc}	2.831 ^{abc}	3.262 ^{a}	2.838 ^{a}	1.123 ^{a}
02	0.723 ^{b}	6.015 ^{a}	4.185 ^{a}	3.108 ^{b}	4.331 ^{a}	3.269 ^{c}	4.238 ^{a}	1.800 ^{a}	1.485 ^{a}	3.831 ^{abc}	2.115 ^{d}	2.269 ^{bcd}	1.746 ^{b}	2.592 ^{a}	1.585 ^{a}
03	0.777 ^{ab}	5.515 ^{abc}	3.638 ^{a}	3.669 ^{b}	3.454 ^{abc}	3.308 ^{c}	4.354 ^{a}	1.348 ^{a}	1.392 ^{a}	3.838 ^{abc}	2.223 ^{d}	2.177 ^{cd}	2.123 ^{ab}	1.923 ^{a}	2.038 ^{a}
	0.266	0.153	0.940	0.105	0.133	0.063	0.758	0.619	0.587	0.306	0.000	0.003	0.114	0.818	0.940
Sig	No	No	No	No	No	No	No	No	No	No	Yes	Yes	No	No	No

^{abcd} Mean values (± Mean) in the same column that do not share a common superscript are significantly different, P≤0.05.

Intensities scored on a 15-point Universal Spectrum intensity scale whereby 0 = none and 15 = extreme

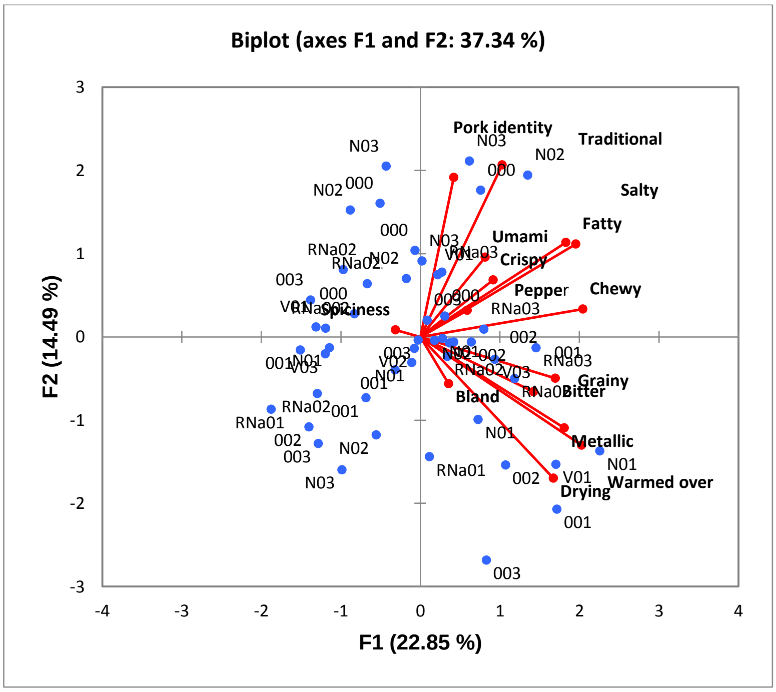

Figure 8.1: PCA of descriptive analysis of breakfast sausages for trained panel

C: Control, RNa: Reduced Sodium Salt, N: NaCl

Table 8.4: Correlations between descriptive sensory attributes used to profile sausages

Variables	Bitter	Bland	Chewy	Crispy	Drying	Fatty	Grainy	Metallic	Pepper	Pork identity	Salty	Spiciness	Traditional	Umami	Warmed
Bitter	**1**	-0.100	**0.265**	0.155	**0.250**	**0.247**	0.147	**0.657**	0.115	0.023	**0.284**	0.119	-0.020	0.108	**0.266**
Bland	-0.100	**1**	**0.177**	-0.007	**0.307**	0.049	-0.017	-0.002	**-0.173**	-0.005	-0.098	-0.166	0.062	-0.055	0.151
Chewy	**0.265**	**0.177**	**1**	0.164	**0.326**	**0.412**	**0.246**	**0.296**	**0.267**	0.101	**0.287**	0.103	**0.379**	**0.217**	**0.394**
Crispy	0.155	-0.007	0.164	**1**	0.061	**0.237**	**0.226**	0.066	-0.060	**0.259**	**0.189**	-0.158	0.105	0.009	0.019
Drying	**0.250**	**0.307**	**0.326**	0.061	**1**	0.119	**0.391**	**0.357**	-0.004	**-0.177**	0.134	**-0.187**	-0.139	-0.008	**0.639**
Fatty	**0.247**	0.049	**0.412**	**0.237**	0.119	**1**	**0.274**	**0.188**	0.057	**0.213**	**0.586**	-0.052	**0.419**	0.152	**0.270**
Grainy	0.147	-0.017	**0.246**	**0.226**	**0.391**	**0.274**	**1**	**0.210**	0.035	0.051	0.091	0.023	-0.115	0.140	**0.360**
Metallic	**0.657**	-0.002	**0.296**	0.066	**0.357**	**0.188**	**0.210**	**1**	0.160	-0.159	0.159	0.081	-0.030	0.172	**0.464**
Pepper	0.115	**-0.173**	**0.267**	-0.060	-0.004	0.057	0.035	0.160	**1**	0.022	0.028	0.158	**0.216**	-0.029	0.073
Pork	0.023	-0.005	0.101	**0.259**	**-0.177**	**0.213**	0.051	-0.159	0.022	**1**	**0.208**	-0.123	**0.359**	**0.190**	-0.159
Salty	**0.284**	-0.098	**0.287**	**0.189**	0.134	**0.586**	0.091	0.159	0.028	**0.208**	**1**	**-0.242**	**0.410**	**0.208**	**0.333**
Spiciness	0.119	-0.166	0.103	-0.158	**-0.187**	-0.052	0.023	0.081	0.158	-0.123	**-0.242**	**1**	-0.030	**0.211**	**-0.233**
Traditional	-0.020	0.062	**0.379**	0.105	-0.139	**0.419**	-0.115	-0.030	**0.216**	**0.359**	**0.410**	-0.030	**1**	**0.249**	0.014
Umami	0.108	-0.055	**0.217**	0.009	-0.008	0.152	0.140	0.172	-0.029	**0.190**	**0.208**	**0.211**	**0.249**	**1**	-0.033
Warmed	**0.266**	0.151	**0.394**	0.019	**0.639**	**0.270**	**0.360**	**0.464**	0.073	-0.159	**0.333**	**-0.233**	0.014	-0.033	**1**

Values in bold are different from 0 with a significance level alpha=0.05. Values close to 0 reflect the absence of absence of a correlation.

Table 8.5: Combined age group consumer attribute means for sausages

Sample	Mean	Std. deviation
C	5.0	2.4
RNa01	3.1	1.6
RNa02	3.9	3.3
RNa03	5.6	1.7
N01	7.1	6.3
N02	5.4	1.1
N03	5.9	1.6
0.1	6.0	1.5
0.2	7.9	1.1
0.3	7.3	1.9

C: Control, RNa: Reduced Sodium Salt, N: NaC

8.2.3.2 Descriptive sensory analysis

The sensory profiling was established using quantitative descriptive analysis. Previous studies have employed this method to analyses meat products (Gomes, Pflanzer, Cruz, de Felício, & Bolini, 2014; Mun, 1998; & Nassu, Gonçalves, da Silva; & Beserra, 2003). Descriptive analysis was conducted using a 15-point scale. A sausage sensory lexicon previously developed by the authors was also used. A trained descriptive sensory panel (n=10) evaluated sausages and were all recruited from University College Cork (Cork, Ireland) and preselected based on interest, availability, non-smoker status, and lack of food allergies, MSG allergies and swallowing difficulties. Their mean age was 27 yrs. old. A total of 7 sessions was conducted over 2 weeks. The panel had previous experience of the evaluation of meat products. Panellists were presented with sausage lexicons to ensure consist results. Panellists individually formed a descriptive profile for each sample. They then developed a lexicon of descriptors to ensure consistency in the application of these descriptors (Table 2). The descriptors used were adapted from previous research conducted on sausages from Chapter 7. Table 8.3 describes the descriptive attribute means. Panellists were trained on how to use the 15cm line scale. A 15cm line scale was used for each descriptor term, anchored at the ends by 'none' on the left hand side and 'extreme' on the right hand side according to AMSA, (1995). Following consistent use of the scale, panellists could identify and scale flavour descriptors using the same intensity scale by discussion of the various references and samples. Analysis was carried out over a four-day period and each sample was evaluated in one session per replication. For aroma evaluation, judges smelled the samples in 3 short sniffs. Analysis of data collected from training sessions confirmed that panel results were consistent, terms were non-redundant in line with previous development of lexicons.

8.2.4 Statistical Analysis

Univariate and multivariate statistical methods were used for analysing the results. Descriptive and consumer data were analysed using the results. Descriptive and consumer data were analysed individually and together. Analysis of variance with means separation and PCA was used to analyse the descriptive data. Chi–squared tests were conducted to compare the consumers' willingness to buy processed meat products. Frequency histograms of consumer results were used to investigate each attribute to determine whether bimodal distributions happened. Analysis of variance with means separation was carried out. Correlation analysis was conducted on descriptive and consumer data individually and together to determine linear relationships. Any nonlinear relationships between consumer attributes and sausage intensities were assessed visually using scatterplots. Internal preference mapping was conducted using XLStat and treatment mean scores were plotted on the resulting principal component eigenvectors. External preference mapping was conducted on the descriptive data and the consumer acceptance scores. Consumer acceptance scores were segmented using PCA followed by cluster analysis. Clusters were confirmed using discriminant analysis. Generalised Procrustes analysis (GPA) was then used to relate consumer clusters and descriptive data. Correlation between QDA and consumer test data was determined using PLS regression analysis. Agglomerative Hierarchical Clustering (AHC) was carried out on the consumer's results. Characteristics of each cluster were determined by analysis of variance of THE acceptance scores within each cluster and examining the external preference map. Analysis was carried out on XLStat 2017.3 (Addinsoft, Paris, France).

8.3. Results and discussion

8.3.1 Descriptive Analysis

The results obtained from descriptive analysis indicated varying distinguished differences between sausages (Table 8.6) (Fig 8.1). Descriptive analysis results displayed distinguishing flavour differences between sausage samples as presented Table 8.3. The descriptors of salty and spicy significantly affected the way in which sausages were perceived. The attributes chewy, grainy, metallic, pepper flavour, umami and warmed-over, did not significantly influence descriptive panel perception. The other attributes varied somewhat between samples. Fig 8.1. displays a PCA plot of the trained panellist's results for sausage samples. Some of the formulations containing 0.1% MSG were characterised by attributes such as metallic, warmed-over and drying. Previous studies have linked umami with a feeling of furriness on the tongue, stimulating the throat, the roof and back of the mouth. Sausages high in salt, such as the control and those containing NaCl and 0.2 and 0.3% MSG were characterised by pork identity and traditional sausage flavour (0.2 and 0.3). One study showed that ratings of pleasantness, taste intensity, and perfect saltiness of low-salt soups were larger when the soup contained umami, whereas low-salt soups without umami were rated as being less pleasant (Roininen, Lähteenmäki, & Tuorilla, 1996). Fatty and salty attributes were associated together. Fat has been hypothesised to influence the perception of saltiness in foods. In a study examining saltiness perceptions using various media, it was found that saltiness intensity was reduced in oily compared with aqueous media (Ohta, Sakamoto, Kondo, & Kusaka, 1979). Oil may act as a barrier between salt and salt taste channels in the tongue. However, others found no effect of oil content on saltiness perception (Metcalf & Vickers, 2002). Control sausages and those containing only 0.3% MSG, with no reduced sodium salt or salt, was associated with pork identity, traditional sausage flavour, crispy, fatty and salty. Correlation analysis (Table 6) revealed significant positive correlations between umami and the 'traditional' attributes associated with sausages such as pork identity, saltiness, spiciness and traditional breakfast sausage flavour. MSG is the sodium salt of the common amino acid glutamic acid. Glutamic acid is naturally present in our bodies, and in many foods and food additives. Glutamate gives rise to Umami perception thus; it is not surprising that the sample containing the highest MSG percentage (0.3%) was associated with exhibiting similar flavour attributes to the high fat and salt control sample.

8.3.2 Consumer Evaluation

The internal preference mapping of consumers aged under 65 yrs. old can be viewed in Fig 8.2. The preference of consumers for sausages containing NaCl and 0.3% MSG and those containing 0.2% MSG with no added salt or NaCl were similar. This age group also associated the sample containing only 0.1% MSG with control sausages as having a similar level of preference. Thus, MSG may be utilised in the under 65 age coho attribute means rt to develop a sausage formulation with a similar preference level to that of a high fat and salt sample. The preference of the consumers aged 65 and over can be viewed in Fig 8.3. The control sample was not well correlated with the new formulations. Food neophobia is defined as reluctance to try novel foods (Pliner & Hobden, 1992). In a study carried out by Meiselman, King, & Gillette, (2010), neophobia was measured with two large (n=1567 and n=6843) commercial samples of US consumers on a 5-point Food Neophobia Scale. Results were compared with demographic data collected in other samples in the US and in other countries. Neophobia was found to increase with age, while decreasing with increasing education and with increasing income. However, the control sausage samples were correlated with those containing reduced sodium salt and 0.1% MSG. This age cohort had similar preferences for sausages with 0.1% MSG, both with and without NaCl. Thus, NaCl may be omitted from certain formulations suggesting that consumers over the age of 65 do not have a preference for sausages containing 0.1% MSG and NaCl and sausages containing only 0.1% MSG. Because consumer results indicated that consumer age affects preference for sausage samples, it is not surprising to find large standard deviations in the mean combined age group consumer preferences for sausages (Table 8.8). This table indicates that the sample containing only MSG had the largest preference among all consumers samples (0.2 and 0.3%). This suggests that consumers have a preference for sausage samples characterised by the following attributes: fatty, salty and spicy (Table 8.4). Based on consumer clustering, Table 8.9 indicates that sausages containing NaCl and 0.3% MSG was ordered first in preference by four consumer clusters and those containing only 0.3% MSG (0.3) and reduced sodium salt and 0.3% MSG (RNa03) were preferred by three consumer clusters. The least preferred samples by consumer assessors were sausages containing reduced sodium salt and 0.1 and 0.2% MSG. These samples differed significantly due to the spicy and salty attributes associated with them (Table 8.4). These results are further emphasised in Table 8.6, whereby sausages containing 0.2% MSG was placed last by four clusters of subjects indicating it was the least preferred by 4 subject cluster.

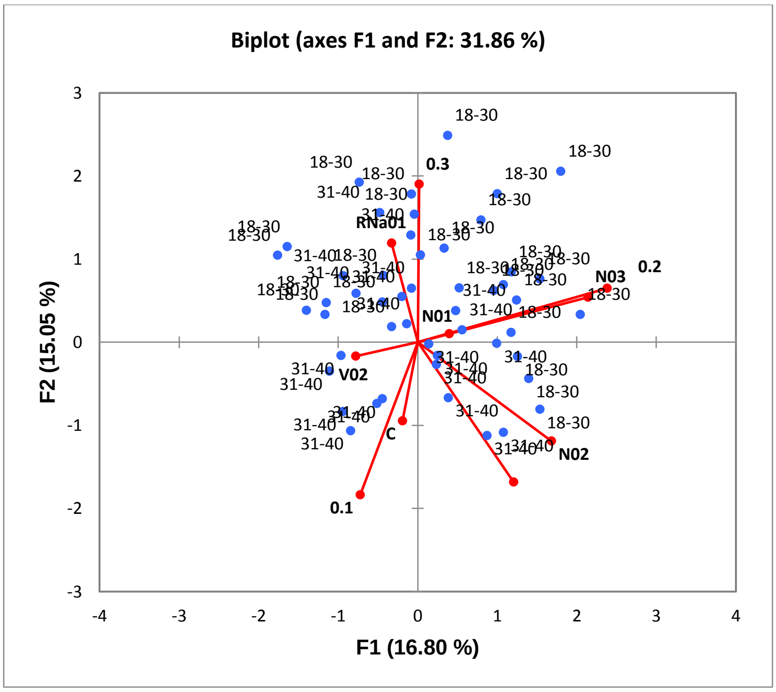

Figure 8.2: Consumers PCA of sausages acceptability and attributes <65

C: Control, RNa: Reduced Sodium Salt, N: NaCl

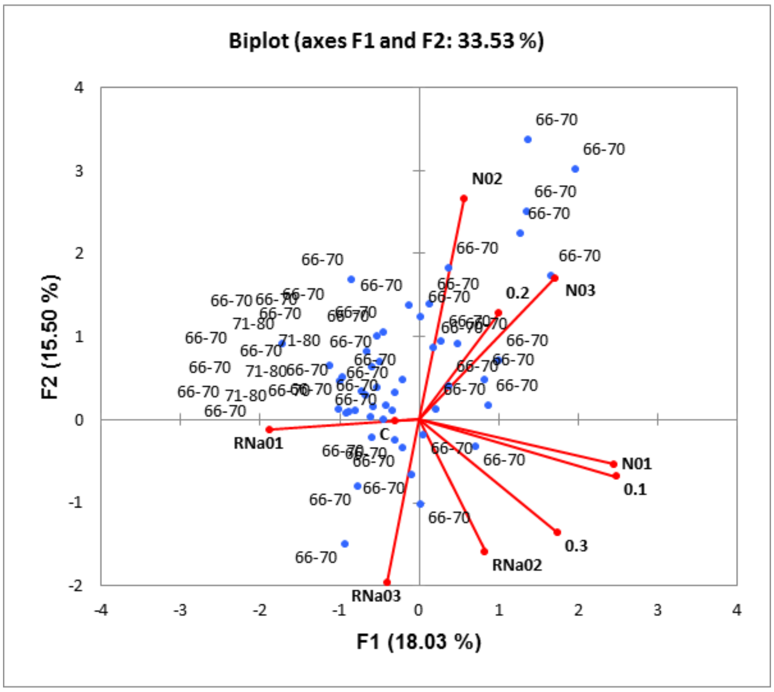

Figure 8.3: Consumers PCA of sausages acceptability and attributes >65

C: Control, RNa: Reduced Sodium Salt, N: NaCl

Table 8.6: Correlations between consumer perceptions of sausages

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Cluster 8	Cluster 9
0.3	0.3	N03	RNa03	N03	RNa03	N03	N03	RNa03
RNa01	RNa02	RNa02	N03	RNa03	N02	RNa03	RNa03	N02
RNa02	RNa01	0.3	N02	RNa02	0.3	RNa02	RNa02	0.2
N02	N02	RNa01	RNa02	N02	RNa02	0.3	0.3	0.1
C	C	N02	0.3	0.3	RNa01	N02	N02	RNa01
0.1	N03	N01	RNa01	RNa01	N03	RNa01	RNa01	0.3
RNa03	0.1	RNa03	C	C	0.2	C	C	RNa02
0.2	RNa03	C	0.2	0.1	0.1	N01	N01	C
N03	0.2	0.1	0.1	N01	C	0.1	0.1	N03
N01	N01	0.2	N01	0.2	N01	0.2	0.2	N01

Objects sorted by increasing preference order

C: Control, RNa: Reduced Sodium Salt, N: NaCl

Table 8.7: Percentage of satisfied assessors

Sample	**%**
C	78%
RNa01	0%
RNa02	11%
RNa03	33%
N01	100%
N02	11%
N03	33%
0.1	89%
0.2	89%
0.3	11%

C: Control, RNa: Reduced Sodium Salt, N: NaCl

8.3.3 Preference Mapping

The preference map of the combined consumer preference data and the data obtained from the descriptive analysis of the trained panel are shown in Fig. 8.5. The contour plot shows the regions corresponding to the various preference consensus levels on a chart whose axes are the same as the preference map. In the regions with cold colours (blue), a low proportion of models give high preferences. On the other hand, the regions with hot colours (red) indicate a high proportion of models with high preferences. Sausages containing NaCl and 0.1% MSG and those containing only 0.1% MSG were the most preferred samples (N01 and 0.1). They were preferred by 80-100% of the trained and consumer panellists combined. The sausage control was preferred by 60-80% of the trained and consumer panellists. The least preferred sausages were those containing reduced sodium salt and 0.2 and 0.3% MSG and those containing NaCl and 0.2% MSG. These results are further reiterated in Table 8.7, where the percentage of satisfied consumers with each product can be seen. Sausages containing NaCl and 0.1% MSG had the greatest assessor satisfaction rating (100%). Many studies have demonstrated the ability to reduce salt in sausages by using MSG as a flavour enhancer. It was determined that it was possible to reduce NaCl by 75% in pork sausages using a modified KCl salt, co-crystallised with ribotide and that the addition of any level of MSG in these products decreased the acceptable level of modified KCl to 50% (w/w) (Pasin et al., 1989). In another study, the flavour intensity of bologna sausages was stronger when MSG or ribotide was added to product formulations. The apparent saltiness was greater when sausages contained MSG, rather than ribotide, or without employing flavour enhancers. Consumers also rated MSG sausages as being more palatable (Ruusunen, Särkkä-Tirkkonen, & Puolanne, 2001). Sausages containing 0.1% MSG and 0.2% MSG with no added NaCl provided the second highest customer satisfaction rating (both 89%). Samples containing MSG gave greater assessor satisfaction than control sausages (78%), which was higher in fat and salt.

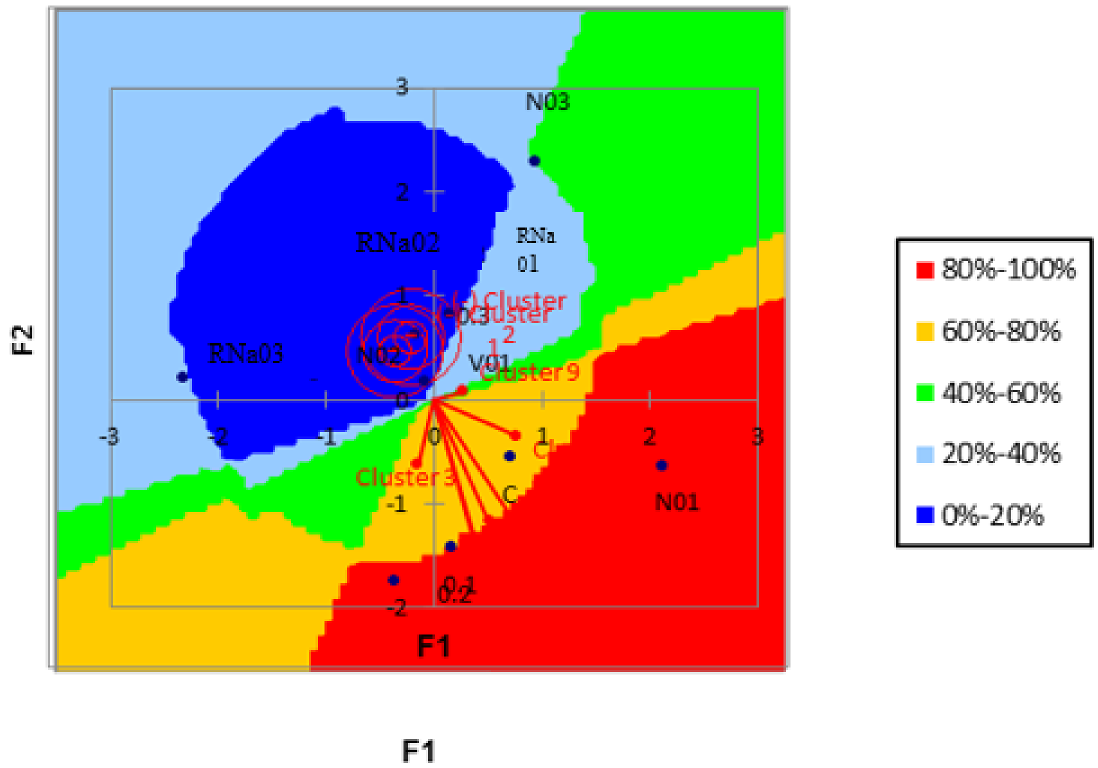

Figure 8.4: External Preference Map of combined consumer data with descriptive analysis result

8.4 Conclusion

This study combined descriptive analysis and consumer evaluation to determine specific flavour profiles for all sausage samples and their relationship for acceptability. The sausage flavour preferences varied among different aged consumers. Consumers aged under 65 had a greater preference for sausages containing MSG at levels of 0.1, 0.2 and 0.3%. Consumers aged over 65 preferred the control sausages and those containing reduced sodium salts and 0.1% MSG, whereas sausages containing NaCl and 0.1% MSG had the greatest overall assessor satisfaction rating (100%), for the consumers and the trained panel combined. These significant relationships indicate that breakfast sausage acceptance is related to spiciness and saltiness and it varies among consumers in specific age cohorts. This information is especially useful for product reformulation with the elderly consumers in mind. Salt, spice and MSG are the underlying flavours associated with both consumer and trained panels preference. This reflects the wider consumer population. This study provides a novel way of evaluating sausages whereby combining consumers of various age cohorts and a trained expert panel we were successful in determining key attributes for the profiling and description of different sausage formulation to generate an overall preferred recipe.

CHAPTER 9

The need for food packaging solutions for the elderly consumers in Ireland

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Abstract

The objectives of this study were two-fold; to assess the general attitudes of the elderly to commodity packaging via a questionnaire survey and evaluation of actual packaging concepts designed for the elderly usage. The packaging concepts employed for assessment among the elderly were meals contained in a control format (vacuum packaged meal), Torus Pak® and a Cryova Darfresh® vacuum-skin packaging technology. Hand grip strength was measured using a dynamometer, to assess health status and to use this measure as a means of quantifying the elderly assessment of package open-ability.

From surveying the elderly participants, consumer age had a huge impact on the choice and rating of packaging. The size of label printing and the use of sharp objects to open packaging were rated as the most prevalent problems associated with food packaging. The incidences of injury sustained as a result of opening food packaging with a sharp object was directly related to age. Ready-meal packaging and carton-based packaging were described as the most difficult packaging to open by participants. From grip strength studies, it would appear that Irish the elderly consumers have a lower mean hand grip strength than observed in other countries. In this study, the two experimental food packaging systems (Torus Pak® and a Cryova Darfresh®) were both preferred by the elderly over the control. This study shows that the elderly have clear likes and dislikes around commodity packaging and that when offered packaging materials and systems that provide aspects of convenience, like ease of opening, they will clearly choose such systems.

Key words: Torus Pak; Cryrovac Darfresh; EQ-5D-5L; Grip Strength; The elderly

9.1 Introduction

The fundamental objectives of food packaging are, in an economical manner, to provide containment, protection, preservation, information and convenience while adhering to environmental and legal requirements (Kerry & Butler, 2008). The aging population is growing dramatically. The 2016 Irish census reported that those aged over 65 had the greatest increase in population since 2011, rising by 102,174 to 637,567, a rise of 19.1%. Not only are the numbers of senior citizens increasing the number of this cohort living independently is also increasing. Over half a million or 577,171 in this older age group lived in private households, an increase of 19.6% from the previous census (CSO, 2016). The ability to cook meals is extremely important for maintaining good nutritional status in this age cohort. For many individuals, in particular ageing consumers, utility will be extremely important. As an individual grows older, well-documented physiological changes occur (Boss & Seegmiller, 1981), which may have an effect on the ability to select and properly use food packaging. This implies that the number of more serious packaging accidents are likely to increase with time. While food, companies are developing more products that cater for the elderly requirement, the packaging associated with such products are materials and formats employed conventionally for able-bodied consumers. New packaging design is a complicated process and requires considerable investments in order to achieve even a slight performance improvement, as any new design must fulfil the packaging fundamentals outlined previously by Kerry & Butler, (2008). Consequently, universal designed food packaging is not yet a common practice. As our society is aging, issues that accompany aging should be factored in to the planning of future food systems. There is very little research conducted assessing the opinions of ageing consumers in relation to product packaging, given that they may encounter difficulties with packaging as they age (Duizer, Robertson, & Han, 2009). In a study carried out in New Zealand examining (n=100) subjects with hand osteoarthritis, participants were asked to open a meat package currently available in supermarkets and a modified, newly designed version and rate their experiences with a consumer satisfaction index (CSI). The mean CSI of the modified pack was 68.9%, compared with 41.9% for the commercial package ($P<0.0001$). The authors concluded that modified packaging would benefit not only people with hand disorders, but also, the population as a whole (Duizer, Robertson, & Han, 2009). Muscle strength has been found to decrease with age (Frontera et al., 2000; Doherty, 2003; Goodpaster et al., 2006; von Haehling, Morley, & Anker, 2010; Marcell, Hawkins, & Wiswell, 2014) and chronic illness (Hughes et al., 2001; Rantanen et al., 2003). As muscle strength declines, older people experience mobility problems and a loss of independence (Goodpaster et al., 2006). Lower-extremity muscle strength is associated with an improvement in performance, resulting in independence, even in the elderly subjects and frail elders (Chandler, Duncan, Kochersberger, & Studenski, 1998). Lower-extremity muscle strength is often measured using a hand-held dynamometer (HHD). Many studies have examined the muscle strength of adults, however, many of these studies only featured the elderly people as part of the study sample (Cuneo, Salomon, Wiles, Hesp, & Sonksen, 1991; Andrews, Thomas, & Bohannon, 1996; Roig et al., 2008; Wind, Takken, Helders, & Engelbert, 2010;). Very few studies have made the elderly people the primary focus of the study (Andrews et al., 1996; Bandinelli et al., 1999; Goodpaster et al., 2006). As there are no present studies examining the effects that hand strength and health status have on the ability of the elderly people to open food packaging, the following study was conducted. The EQ-5D is arguably now the most well-known and commonly used generic measure of health status internationally. The EQ-5D-5L, was a follow-on from EQ-5D. It was established to advance sensitivity and to standardise the language used across dimensions (Herdman et al., 2011). The EQ-5D-5L is comprised of five dimensions; mobility, self-care, usual activities, pain/discomfort and anxiety/depression. It increases the available response options (levels) from three to five (no, slight, moderate, severe, and extreme problems/unable to). The EQ-5D-5L is commonly being incorporated into routine data collection in clinical settings, clinical trials and population health surveys, such as the GP Health Survey for England (Fuller, Mindell, & Prior, 2016). It is also used in local initiatives. For example, the Cambridgeshire Community Services NHS Trust collects EQ-5D-5L data to evaluate outcomes from rehabilitation services (Cambridgeshire Community Services NHS Trust, 2013–2014). Its design accounts for the need for a direct link between the measurement and valuation of health, whereby every health state that patients might report on, the EQ-5D-5L instrument can be summarised by a single value. Consequently, the objectives of this study were to survey ageing consumer attitudes towards current food packaging materials and formats used in products with which they are familiar and the effect muscle strength and health status have on the ability of the elderly consumers to open experimental ready-meal packaging formats which were employed as a primary focus of this study.

9.2. Materials and Methods

The study was divided into two parts: a quantitative survey examining shopping habits and senior consumer attitude to retail packaging materials and formats; and a hand a strength study, health status study and a packaging preference test employing packaging systems which have the potential to be adopted for use with the elderly-friendly food product design.

9.2.1 Consumer Survey

A hundred and two community-dwelling older persons (66 women, 34 men) were recruited to participate in this study (Table 9.1). The eligibility criteria for participants had to be at least 65 years old with a history of regularly consuming ready-meals, living in their own home, responsible for their food choices and cooking their own food. Subjects read and signed the informed consent documents before assessment began. The survey was divided into three sections. Firstly, information pertaining to; age group, gender, shopping frequency, and number of ready-meals purchased per week was recorded (Table 9.1). Secondly, questions to problems consumers associated with food packaging were asked (Table 9.2). Packaging technology and science nominal scales with appropriate anchors were used to collect this information. Participants were asked to indicate, using 5-point scales, labels of ‘Never’, ‘seldom’, ‘sometimes’, ‘frequently’ and ‘very often’. The consumers were asked to choose the type of packaging they found most difficult to open from the following list; ready-meals, carton-based packs, bags, cardboard boxes, tins and bottles/jars. The packaging materials selected for use in the survey represented a range of those most commonly found on the Irish market. They were also asked if packaging influences their purchasing decisions on different products (Table 9.3).

Table 9.1: Demographic data of consumers (n= 102)

Age group (yrs. old)	Frequency (%)
66-70	45
71-80	35
81-85	12
85+	8
Gender	
Male	34
Female	66
Frequency of food shopping	
1/day	12
2-3 times/week	33
1/week	48
1/fortnight	7
Number of ready meals purchased per week	
<1	24
2-3	63
3-4	5
5+	8

Table 9.2: Incidences of problems consumers associated with food packaging

Problems	Never (%)	Seldom (%)	Sometimes (%)	Frequently (%)	Very Often (%)
Label printing is too small to see cooking/reheating instructions	0.0	1.3	1.1	21.3	76.3
Outer packaging is too hard to remove	1.5	2.5	3.8	74.2	18.0
Spillage when opening the package	4.0	5.0	6.2	64.2	20.6
Too heavy to carry	6.9	20.0	8.6	44.4	20.1
Too hot to handle	2.1	2.3	31.0	47.3	17.3
Steam burn when removing the plastic cover	0.2	25.4	4.2	39.4	30.8
Need a sharp object to open the plastic seal	0.0	0.0	4.8	8.1	87.1
Hard to grip the plastic seal	4.6	5.1	8.8	61.1	20.4

Table 9.3: Results of age effects on shopping frequency, the effects packaging has on consumer purchasing and types of packaging the consumers found most difficult to open

	Shopping frequency (n)			**Does packaging influence your purchasing? (n)**		**What type of packaging do you find most difficult to open? (n)**					
Age	**1/day**	**2/week**	**1/week**	**Yes**	**No**	**Ready meals**	**Tetra Packs**	**Bags**	**Cardboard boxes**	**Tins**	**Bottles**
<65	10	16	11	11	26	12	12	2	1	10	0
<75	16	21	15	16	36	17	16	7	1	7	4
<85	8	3	2	3	10	2	5	2	0	0	4
Age group effect on Question (Sig)	**0.000*****			**0.027****		**0.003****					

** = ($P \leq 0.01$), *** = ($P \leq 0.001$), n = number of respondents

9.2.2 Focus group

Upon completion of the survey, participants were invited to participate in a focus group. The details of those interested (address, phone number and e-mail address) were taken to arrange focus group times. The focus group was held with the survey participants who expressed an interest in attending the focus groups (n =28). Table 5 outlines the gender and age group of the subjects.

Table 9.4: Focus group subject characteristics

Gender	**%**
Female	71.4
Male	28.6
Age group	
<65	10.7
<75	53.6
<85	35.7
Sample A	0
Sample B	60.7
Sample C	39.3
	Mean
Dominant hand strength (kg)	16.5
EQ-VAS-5L Index	74

9.2.2.1 Packaging

A meal solution comprising the packaging was sourced from Versitile Packaging Ltd, Silverstream Business Park, Silverstream, Monaghan, Ireland. Sample A was the control sample. This sample was characterised by the fact that it is a conventionally used retail packaging system and that a great deal of force was required to open it. The space provided to hold the tear tab was so small that it was impossible to open the package on first attempt. Another parameter associated with this package was the fact that a sharp object was needed to pierce the film prior to being microwaved. The control package was a vacuum packaged meal solution and currently available on the market. The control sample was purchased from a local supermarket. Prior to testing, the outer packaging sleeve was removed to prevent bias. The meal was heated in the microwave according to the reheating guidelines outlined by the manufacturer as presented on the packaging sleeve.

The main objective of the technically modified packaging was to reduce the opening force required. After evaluating various packaging solutions, including; vacuum packing, vacuum-shrink packaging, vacuum-skin packaging and modified atmosphere packaging, two packaging solutions were decided upon as they were novel to the market and both featured easy-to-open features. A meal solution comprising of mashed potatoes and sausages were utilised. All packaging samples were standardised by calculating the dimensions of the trays and relating it to the meat and potato quantity. The meal solutions were packaged in the packaging facility in University College Cork. A pilot trail was firstly carried out in order to determine the optimum sealing times of sample B and sample C. Sample B featured the Torus Pak®. An outline of the mechanism is illustrated In Fig 9.1. This packaging is a "Straight-to-Plate" packaging solution for single portion meals (Fig 9.1A) that features a removable bottom which offers the unique possibility to easily serve the packaged meal on a plate and still have the food presented as it appeared within the package. A pull tab (Fig 9.1B) located at the bottom of the package allowed for the meal to be dispensed easily onto the subject's plate (Figs 9.1C & 9.1D). The meal solution was heat-sealed using a Leif Åhl Verkstad Tray Sealer, Saleby, Erik-Larsgården, 11 SE-531 93 Lidköping, Sweden. The meal was reheated in a microwave at a temperature of 800 watts for 3min.

Sample C featured Cryova Darfresh® vacuum-skin packaging technology which enables products to be cooked, (or reheated) by the consumer in a microwave (Fig 9.2A). The package does not require ventilation holes to be punctured into the packaging before microwave heating and during product heating, the vacuum-skin forms a bubble (Fig 9.2B), the material self-vents (Fig 9.2C) and relaxes over the product for easy peeling. The stay cool handles reduce the risk of burn as the tray is removed from the microwave (Fig 9.2D). The meal solution was packaged using the Sealed Air–Cryovac Food Packaging System, Western Industrial Estate, Naas Road, Dublin, Ireland.

Figue 9.1: Sample A featured the control sample

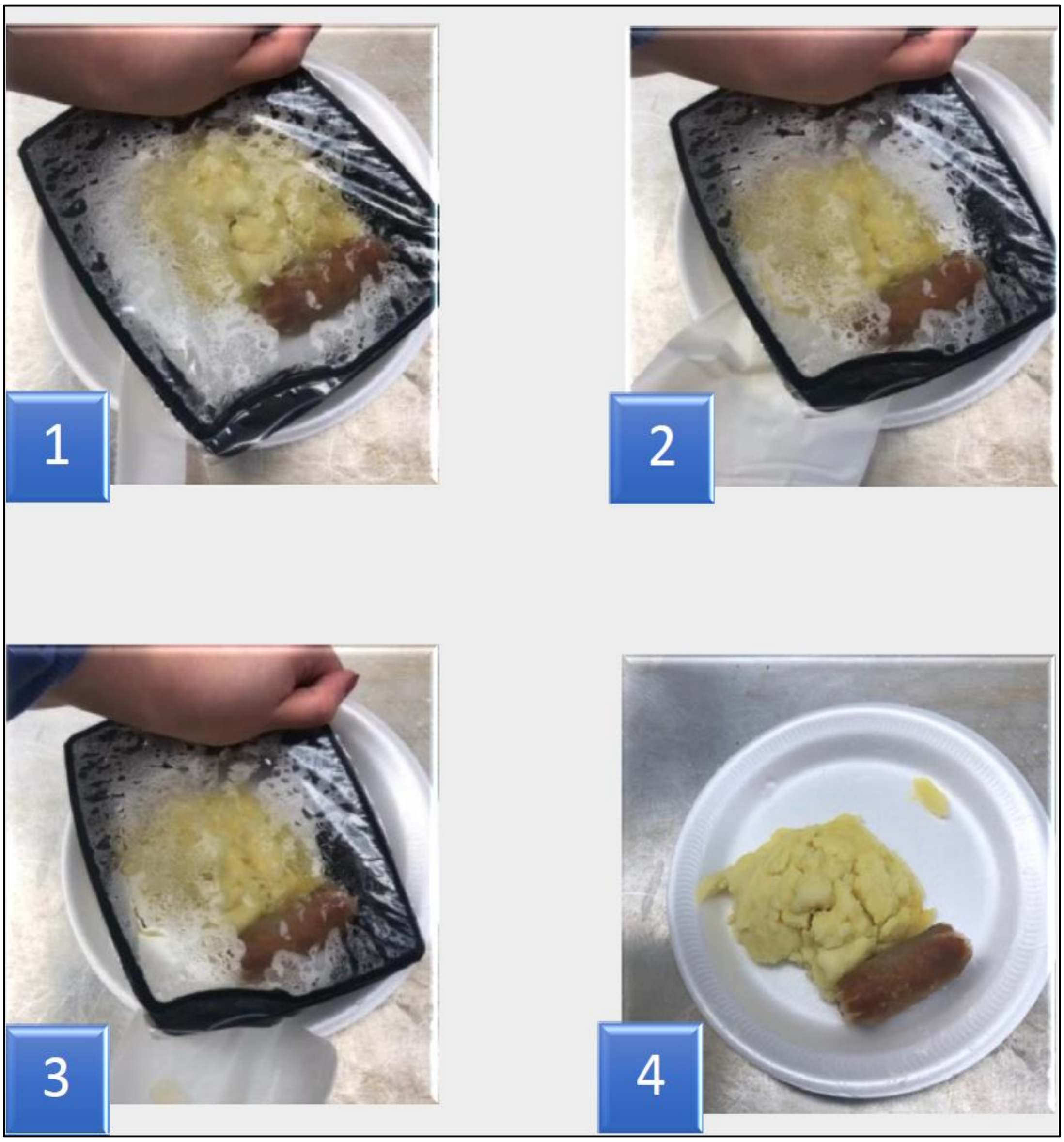


Figure 9.2: Sample B featured the Torus Pak®. This packaging is a "Straight-to-Plate"

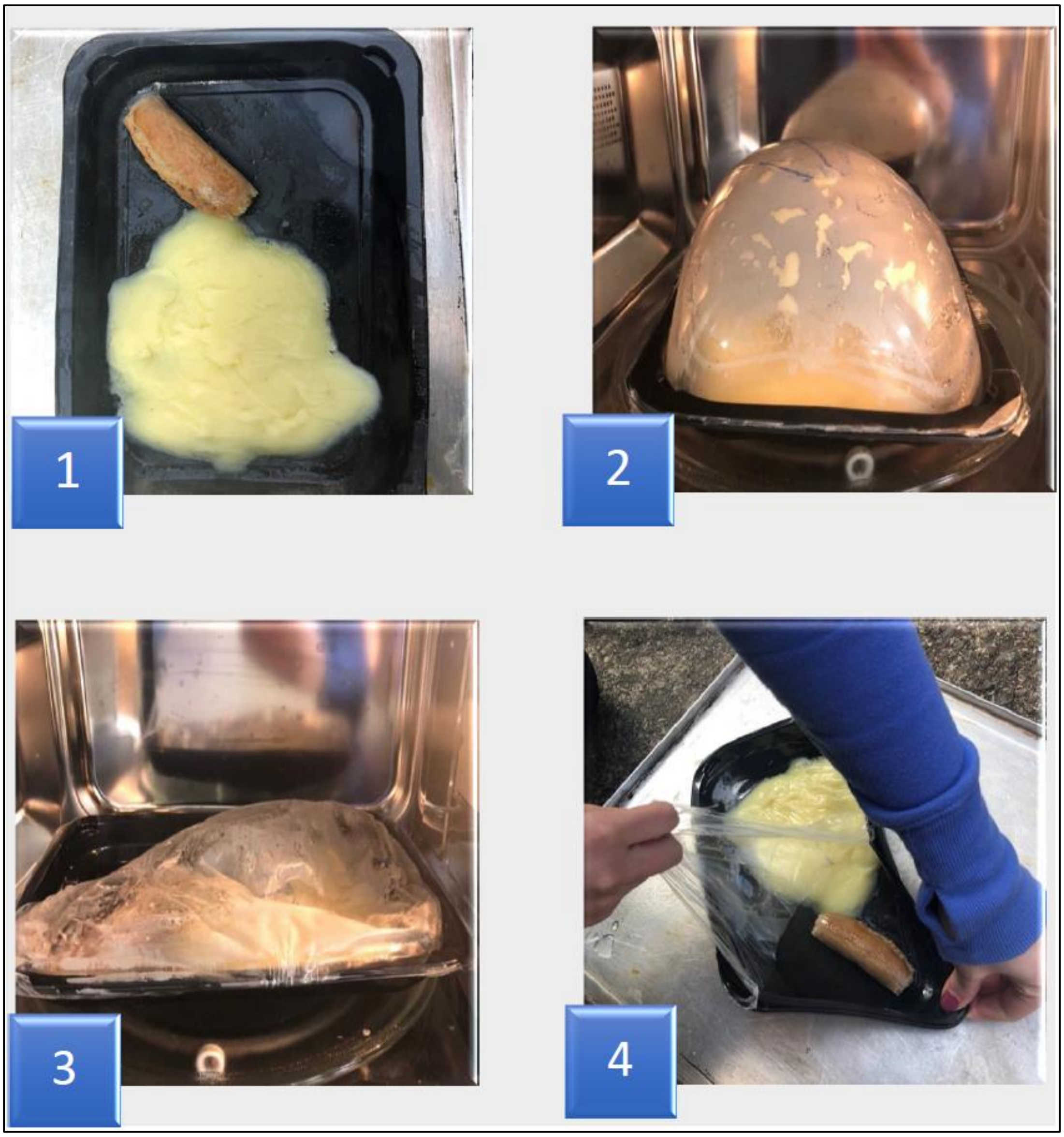


Figure 9.3: Sample C: Cryovac Darfresh® vacuum skin packaging technology

9.2.2.2 Test procedure

One by one, the members of the focus group used the microwave and followed the reheating instructions. Before assessment began, the members of the focus group were demonstrated the correct method of opening the packaging. They were also asked to refrain from using any sharp objects to open packages B or C. All packaging was devoid of text or illustration and only featured a random three-digit code. Then each member of the focus group opened the packaging and filled out a questionnaire for each packaging type (A, B & C). The questionnaire included a section where participants were able to indicate their preferred packaging.

9.2.2.3 Clinical measurements

Hand grip strength was measured using a JAMAR ® Plus+ Electronic Hand Dynamometer, Patterson Medical®, Sutton-in-Ashfield, Nottinghamshire, NG17 2HU, UK. According to The American Society of Hand Therapists (ASHT), grip strength was measured using the Jamar dynamometer with its handle in the second position. Participants were seated with their shoulders adducted, their elbows flexed at 90◦, and their forearms in a neutral position according to ASHT (Fess, 1992). Ten measurements for each hand (right & left) were recorded. The instrument also recorded the mean, standard deviation and coefficient of variation for each measurement. The gender, age and dominant hand of each subject was noted (Table 9.4).

9.2.2.4 Health status

Consent was obtained from EuroQol Office to utilise the EQ-5D-5L instrument in this work. EQ-5D is a standardised measure of health status developed by the EuroQol Group in order to provide a simple, generic measure of health for clinical and economic appraisal (EuroQol, 1990). EQ-5D measures five dimensions of health (mobility, self-care, usual activities, pain/discomfort and anxiety/depression), within three levels corresponding to “no problems”, “some problems”, and “extreme problems”-giving a total of 243 unique composite health states. In this study, the UK time, trade-off values were used to convert the states to health utility scores, as there is none currently established for Ireland. This utility-based EQ-5D index score ranges from −0.59 to 1.00, with negative values representing health states worse than being deceased, 0.00 representing being deceased and 1.00 representing the state of full health (Dolan, 1997). Socio-demographic characteristics, such as; age, sex, ethnicity, marital status, educational level, employment status, income and housing-type were captured using a structured questionnaire. The EQ-5D-5L health states was converted into a single index value. The index values, presented in country-specific value sets are a major feature of the EQ-5D instrument, facilitating the calculation. The questionnaire can be viewed in Fig 3. The EQ-5D-5L Crosswalk Index Value Calculator was used according to methods outlined by van Hout et al. (2012).

Under each heading, please tick the ONE box that best describes your health TODAY

MOBILITY

I have no problems in walking about ☐
I have slight problems in walking about ☐
I have moderate problems in walking about ☐
I have severe problems in walking about ☐
I am unable to walk about ☐

SELF-CARE

I have no problems washing or dressing myself ☐
I have slight problems washing or dressing myself ☐
I have moderate problems washing or dressing myself ☐
I have severe problems washing or dressing myself ☐
I am unable to wash or dress myself ☐

USUAL ACTIVITIES *(e.g. work, study, housework, family or leisure activities)*

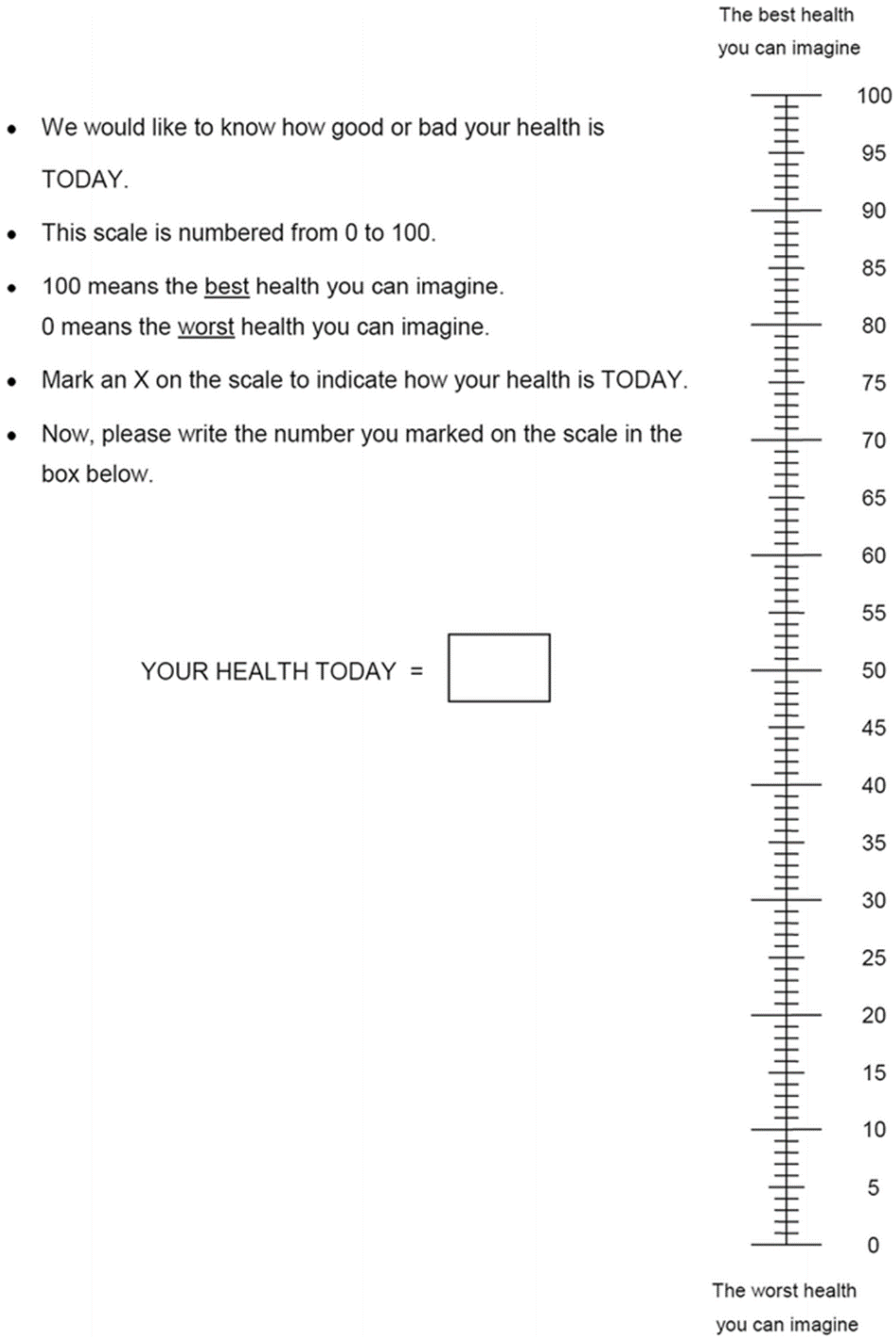
I have no problems doing my usual activities ☐
I have slight problems doing my usual activities ☐
I have moderate problems doing my usual activities ☐
I have severe problems doing my usual activities ☐
I am unable to do my usual activities ☐

PAIN / DISCOMFORT

I have no pain or discomfort ☐
I have slight pain or discomfort ☐
I have moderate pain or discomfort ☐
I have severe pain or discomfort ☐
I have extreme pain or discomfort ☐

ANXIETY / DEPRESSION

I am not anxious or depressed ☐
I am slightly anxious or depressed ☐
I am moderately anxious or depressed ☐
I am severely anxious or depressed ☐
I am extremely anxious or depressed ☐


The best health
you can imagine

- We would like to know how good or bad your health is TODAY.
- This scale is numbered from 0 to 100.
- 100 means the best health you can imagine.
0 means the worst health you can imagine.
- Mark an X on the scale to indicate how your health is TODAY.
- Now, please write the number you marked on the scale in the box below.

YOUR HEALTH TODAY =

100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0

The worst health
you can imagine

Figure 9.4: EQ-VAS scoring questionnaire presented to the focus group

9.3. Statistical analysis

9.3.1 Consumer survey analysis

The data received from the consumer survey questions were coded by assigning a number to each scale. Numerical data were then analysed using SPSS (Version 18.0 SPSS Inc. Chicago, IL, USA). Frequencies of responses were calculated for each question. Cross tabulations and Chi-square tests were used to determine the relationships between various nominal variables using SPSS 18.0.

The relationship between preferred packaging and grip strength of dominant hand, gender, age and EQ-5D-5L index value was calculated using a logistic regression model. The level of significance was set at $P \leq 0.05$. Kolmogorov – Smirnov tests and Q-Q plots confirmed the normal distribution of the data. Descriptive statistics with mean and standard deviation were used for analysis of continuous variables. Using a t – test for dependent groups, the difference between type B and type C packaging was measured (type A was omitted as 0% of respondents indicated that they liked this packaging). These results were presented with 95% confidence intervals. Analyses of variances (ANOVA) were used to test whether the means of preferred packaging differed statistically in various respondent groups. Firstly, one-way analysis of variance was performed using each of the statements regarding the preferred packaging as dependent variables. The age group, gender, were used as independent variables.

9.4 Results & discussion

The demographic data obtained from the consumer study is recorded in Table 9.1. The majority of the respondents were female and aged between 60 and 65 years old, with the frequency of food shopping carried out mostly once per week. The majority of respondents stated that they purchased ready-meals 2-3 times per week. Table 9.2 illustrates the survey data obtained from the consumers. The incidence of the label printing was established as being too small to view cooking and reheating instructions by 76.3% of consumers. Ford et al. (2016) found similar results, where the most common age-related challenges associated with packaging were found to include small font size, and unclear description images (Ford, & Simms, 2016). Spillage when opening the packaging was recoded as a frequent occurrence by the majority (74.2%) of respondents, so too was, too hot to handle (47.3%), steam burn when removing the plastic lidding film or cover (39.4%) and difficulty in gripping the plastic seal for pulling or tearing purposes (61%). Duizer et al. (2009) found that the most common problems associated with food packaging, included; tight lids and spillage during opening. Interestingly 87.1% of consumers interviewed in this study indicated that they very often needed to employ a sharp object to open the plastic seal. The main problem associated packaging issues are the large forces required to open packaging (Dittrich, & Spanner-Ulmer, 2010). Table 3 demonstrates the age group incidence of those who have incurred an injury after using a sharp object to open meat packaging. From this table the oldest elderly category (>65) had the greatest incidence (36.9%) of injury, while the youngest the elderly group had the lowest incidence (66.7%) of injury obtained from using a sharp object to open meat packaging. Caner & Pascall (2010) found that the main instruments used to open packaging are scissors, knives and blades, leaving older consumers at a greater risk of feeling vulnerable should an accident occur.

In the consumer study examining ageing and consumer attitudes towards food packaging mentioned previously, it was determined that 61% of participants had asked for assistance opening some form of packaging. This was found to be most prevalent in individuals with weakness in their arms, hands or wrists. Previous research has shown that the due to changes in physical capabilities, older people are at risk of serious injury as a result of difficulties opening packaging (Hudson & Hartwell, 2002). Table 9.3 records the tests of between subject effects. The age group of the consumers significantly affected the frequency of shopping, the influence packaging has on purchasing and the types of packaging rated as the most difficult to open. The majority of those aged <65 and <75 did their grocery shopping twice per week, whereas the majority of those aged <85 did it more frequently i.e. once per day. Packaging significantly influenced the different age groups in terms of purchasing food products, and significant differences were observed for packaging types that consumers found most difficult to open. Carton and Tetra packs, and ready-meals, were recorded as the most difficult to open by all three age categories. Table 9.4 describes the gender, age group and preferred packaging sample from focus group participants. The table also records the mean dominant hand strength as 16.5kg with 16.84kg recorded for men and 16.15kg recorded for women. The mean EQVAS-5L index value was determined to be 75.

The mean hand grip strength recorded for our study participants was relatively lower than that recorded for similar participants from other countries. Previous research has recorded 23-25kg in German women and 29-40kg in German men (Dodds et al., 2014). Great Britain’s mean hand grip strength for men (n=3,947); was 42kg and for women (n=4,171) was 25kg. Peters et al. (2011) recorded mean hand grip strength in the USA of those aged between 60-69yrs. old as follows: men 43kg and women 25kg. Massy-Westropp et al. (2011) analysed hand grip strength in North West Adelaide, Australia and found those aged between 60-69yrs. old had the following hand grip strength: men 40kg and women 24kg. Research was carried out on

Irish (n=5,819) participants by Kenny et al. (2013). Hand grip strength was related to participant height. Men aged 65 and over had a hand grip strength of 34kg if their height was <173cm and 38kg if their height was greater than 173cm; women age 65 and over recorded a mean hand grip strength of 20kg if their height was less than 160cm and 23kg if their height was greater than 173cm. Men aged over 75 yrs. old had a mean hand grip strength of 29kg if their height was less than 173cm and 34kg if their height was over 173cm; similarly women aged over 75 yrs. old had a hand grip strength of 18kg if their height was less than 160cm and 20kg if over the height of 160cm. All of the studies listed used the Jamar dynamometer, however, the Irish study carried out by Kenny et al (2013) used the BASELINE Dynamometer. The low mean hand grip strength recorded in our study for those aged over 65 yrs. old is much less than the other counties listed above, but are similar to the Irish study conducted by Kenny et al. (2013). Grip strength has been proven to decrease with age, even in healthy subjects (Werle, Goldhahn, Drerup, Simmen, Sprott, & Herren, 2009). Marks et al. (2012) stated that the elderly subjects with hand dysfunctions were only able to apply 53% of the force on packaging than healthy subjects.

A logistic regression was performed to ascertain the effects of age, hand strength, EQ-5D-5L index value and gender on the participants preferred packaging. No significant differences were noted, with the exception noted for age interaction. The EQ-VAS score in this study was relatively higher (EQ-VAS mean = 74) than that of older subjects in previous studies from different countries. In a multi-country study examining the effects of disease on EQ-VAS score, the following results were noted between the different countries; Denmark (mean age =60.5) had an EQ-VAS mean of 60, the Netherlands (mean age 61.7) had an EQ-VAS mean of 61.7, Poland (mean age 69.9) had an EQ-VAS mean of 52, Scotland (mean age 72.8) had an EQ-VAS mean of 64 (Janssen, Pickard, Golicki, Gudex, Niewada, Scalone, & Busschbach, 2013). The respondents in our focus group had a higher health score than other countries based on their age grouping. Significant differences were observed for the correlation between most preferred packaging and difficulty experienced opening the food packaging. This indicated that the ability to open food packaging is important for determining the perceived preference. A total of 82.4% of participants involved in the study and preferred type B packaging to type C (81.8%). Hand and finger strength are known to decrease with age (Sormunen, Nevala, & Sipilä, 2014). Many studies have found similar results to this study, whereby it has been found that the ability to open and handle packaging are key factors determining the ease of packaging usage (Bell, Walton & Tapsell, 2016; Heiniö, Pentikäinen, Rusko, & Peura-Kapanen, 2014). Research has shown that the elderly consumers (>65 yrs. old) are more brand loyal than younger consumers, providing opportunities for well-designed products in the market (East, Uncles, & Lomax 2014). Table 6 indicates a significant effect on health score index. According to this data, there is a great need for user-friendly, publicly-available, validated models that would allow a processor to enter specific product conditions and process parameters for each stage of the packaging process that could allow the generation of product temperature profiles and rates of pathogen inactivation. This in turn could be used in the design and control of ready-to-eat meats (Kerry & Kerry, 2011). Future packaging solutions for the aging consumer will need to focus on ensuring that the provision of information in a clear and unambiguous manner is achieved, along with numerous measures which deliver layers of convenience, in portion packs that meet purchasing and usage requirements, sold in shelf-stable packaging formats which may need to communicate all of this to the elderly consumer through active dialogue.

Table 9.5: Effect of gender on health status, and dominant hand score

Value	Gender	Mean (kg)	Std. Deviation	Std. Error Mean	Sig.
Health Score Index	Male	69	0.34	0.12	0.035*
	Female	78	0.17	0.04	
Dominant hand score	Male	16.84	9.38	3.32	0.20ns
	Female	16.15	7.12	1.59	

ns = non-significant & * = ($P \leq 0.05$)

Table 9.8: Comparison of three packaging types from the focus group

		Package					
Question	**Response**	**A**	**%**	**B**	**%**	**C**	**%**
Did you experience any difficulty opening the food package?	**Yes**	18	64.3	9	32.1	10	35.7
	No	10	35.7	19	67.9	18	64.3
Did the steam burn you when you opened the seal?	**Yes**	25	89.3	6	21.4	5	17.9
	No	3	10.7	22	78.6	23	82.1
Did you find this food package too hot to handle?	**Yes**	9	32.1	2	7.1	2	7.1
	No	19	67.9	26	92.9	26	92.9
Did you find the seal easy to grip?	**Yes**	3	16.7	21	75	18	64.3
	No	25	89.3	7	25	10	35.7
Would you buy food package like this again?	**Yes**	28	100	21	75	12	42.9
	No	4	14.3	7	25	16	57.1
Would you be willing to pay more for this food package compare to other ready meals on the market?	**Yes**	24	89.3	16	57	12	42.9
	No	1	3.6	12	42.9	16	57.1
Is the size too big?	**Yes**	27	96.4	2	7.1	8	28.6
	No	6	21.4	26	92.9	20	71.4
Is the size too small?	**Yes**	22	78.6	7	25	10	35.7
	No	18	64.3	21	75	18	64.3
Is the size just right?	**Yes**	10	35.7	20	71.4	20	71.4
	No	5	17.9	8	28.6	8	28.6
Do you think this is a convenient type of packaging?	**Yes**	23	82.1	23	82.1	20	71.4
	No	3	10.7	5	17.9	8	28.6
Do you think this is a safe type of packaging?	**Yes**	25	89.3	22	78.6	21	75
	No	20	71.4	6	21.4	7	25
Do you like the shape?	**Yes**	8	28.6	21	75	25	89.3
Did you experience any difficulty opening the food package?	**No**	18	64.3	7	25	3	10.7

9.5. Conclusions

This study provides evidence that adaptions for packaging provide the aging consumer with a safer and less stressful experience when opening food packaging. This study indicates that Irish the elderly consumers have a lower mean hand grip strength than other countries. This information may explain the great difficulties Irish consumers experience with packaging and the high incidences of injury related to food packaging. The preferences for the two modified food packaging bears this out. None of the focus group subjects had a preference for the common vacuum food packaging (experimental control) found in supermarkets. By technically modifying food packaging, independence and ability to live at home may be an option for a greater number of seniors. Modified packaging with older consumers in mind may also decrease the incidences of injuries experienced by our growing ageing population. The results obtained from this study indicate that technical optimisation is a successful way to optimise food packaging for the elderly consumers and that this consumer grouping can clearly identify common packaging issues that affect them.

CHAPTER 10

Discussion & conclusion

Discussion

The principal objective of this thesis was to develop a meal solution with the elderly consumers in mind. This objective was undertaken by focussing on the challenges experienced by older consumers on a daily basis in relation to food and food packaging. Research commenced by conducting a survey to determine consumer's perceptions of meat and processed meat in Ireland.

This step, which is outlined in Chapter 2 was fundamental in establishing a base line whereby the other chapters were established. Overall consumers showed a preference for sausages, rashers ham and corned beef. Preferences for processed meat was established for denture wearers and those with swallowing difficulty. Indicating that fresh meat on the market may be too tough for this genre of consumers to chew and swallow. From this work, it was apparent that research was needed into the texture and flavour of meat and meat products based on age groupings.

Chapter 3 focused on the hypothesis that various texture levels are accepted by different age cohorts. A fresh meat product was utilised for this study. Steak dry aged at different time points (2, 7 and 21 days) demonstrated poor identification of tenderness classifications in those aged 71-85. This study demonstrated that changes in textural perception occur with age.

Another beef product was then evaluated in Chapter 4. In this chapter, a processed meat product was evaluated. Assessment of salt reduction was carried out on corned beef using Kl (potassium lactate) as a salt replacer. It was found that NaCl levels currently added to corned beef are too high for consumer acceptance, the participants all accepted levels closer to recommended salt targets. The study also suggested that Kl may be added to corned beef as a salt replacer for those aged over 65, as this age cohort did not notice any sensory differences to the product. From this study, it was clear that different salt levels and replacers are favoured among different age cohorts.

Another study was carried out on sausages whereby varying levels of fat and salt were investigated. The 18-40 yr. olds preferred sausages containing 20% fat, 41-64 yr. olds preferred sausages with 15% fat, 65+ age group preferred sausages containing 30% fat. The 18-40 yr. olds preferred high salt samples, 41-64 yr. olds displayed no salt preference, while the 65+ age group preferred high salt sausages. Sausage formulation choice was found to be driven by texture for the younger age cohort, flavour for the middle age cohort and visual aspects from the oldest age cohort. From this study it was clear that texture, flavour and visual perception of foods were age determined factors involved in sensory evaluation.

Chapter 6 focused on flavour enhancement of breakfast sausages. This study indicated that by adding 0.2% MSG to sausage formulations, perception of meat flavour increased in those aged under 20 yr. old. The 21-40 age cohort's sensory perception was influenced by a 0.1% change in MSG. The 41-64 age cohort displayed decreased perception for NaCl, compared to the younger age cohorts. The 66-75 yr. olds did not like samples that contained 0.3% MSG, whereas 76-80 yr. olds did. The 61-65 and 66-75 age cohorts were more influenced by texture than younger age cohorts. The effects that MSG has on intensity and hedonic attributes are very specific to consumer groupings based on age. Again, the influence texture and flavour have on sensory perception were found to be hugely attributed to age grouping.

Progressing from this knowledge it was essential that when developing the new product for that it would be passed by a trained sensory panel, as this is the Gold Standard of product evaluation from a sensory perspective. Quantitative Descriptive Analysis (QDA) was used to explore the sensory variation of ten sausage samples which included salt and fat reduced sausage and MSG (Monosodium glutamate) flavour enhanced sausages, which were established from the results of Chapter 5 and 6. A panel (n=8) was trained using a bespoke lexicon and a flavour wheel was generated for 15 attributes deemed to be most relevant to these products. Primary flavour differences between low - fat and low - salt sausages compared to a control sample were identified as: bitter, bland, chewy, crispy, drying, fatty, grainy, metallic, peppery, pork identity, salty, spicy, traditional sausage flavour, umami and warmed-over. This study presents a list of product attributes (lexicons) and a sensory wheel which may be used as a reference for describing fat and salt reduced pork sausages for applications in research in meat product development. MSG was found to reduce the perception of spiciness, by enhancing other attributes such as saltiness in sausages. Samples containing salt and 0.2% MSG was equal in terms of salt perception to the control samples as determined by QDA.

As these sausage formulations passed a trained panel it was essential that consumers accepted them too. For this reason, preference mapping was an ideal tool whereby the descriptive sensory profiles for sausage treatments were determined using a trained panel (n=10) and employing established sausage flavour lexicons from Chapter 8. Sausages were evaluated for consumer acceptability by varying age groups (18-85 years old). Consumers (n=288) assessed sausage treatments in terms of preference. A preference map was generated utilising data obtained from the trained panel (Chapter 8) and the consumer panel

(Chapter 6). The objectives of this study were to evaluate the flavour profile and acceptability of 10 sausage formulations varying in MSG, salt and fat levels using descriptive analysis and consumer acceptance tests; and to determine drivers for liking by applying external preference mapping and highlighting the relationship between descriptive attributes and hedonic judgements using partial least squares methodology. Sausage formulations (n=10) ranging in salt (0.0-2.5%), fat (15-30%) and MSG (0.0-0.3%) were investigated. Sausage flavour preferences varied among different aged consumers. Consumers aged under 65 had a greater preference for sausages containing MSG at levels of 0.1, 0.2 and 0.3%. Consumers aged over 65 preferred control sausages and those containing reduced sodium salt and 0.1% MSG, whereas considering the greatest overall assessor acceptance, the sample containing NaCl and 0.1% MSG displayed the greatest acceptability. These significant relationships indicated that breakfast sausage acceptance is related to spiciness and saltiness and it varies among consumers in specific age cohorts.

With the ideal formulation generated from a consumer and a trained panel point of view (Chapter 8), package design was the final step in the process to design a complete meal solution for aging consumers. The objectives of the packaging (Chapter 9) study were two-fold; to assess the general attitudes of the elderly to commodity packaging via a questionnaire survey and evaluation of actual packaging concepts designed for the elderly usage. The packaging concepts employed for assessment among the elderly were meals contained in a control format (vacuum packaged meal) Torus Pak® and a Cryova Darfresh® vacuum-skin packaging technology. Hand grip strength was measured using a dynamometer, to assess health status and to use this measure as a means of quantifying the elderly assessment of package open ability.

From surveying the elderly participants, consumer age had a huge impact on the choice and rating of packaging. The size of label printing and the use of sharp objects to open packaging were rated as the most prevalent problems associated with food packaging. The incidences of injury sustained as a result of opening food packaging with a sharp object was directly related to age. Ready-meal packaging and carton-based packaging were described as the most difficult packaging to open by participants. From grip strength studies, it would appear that Irish the elderly consumers have a lower mean hand grip strength than observed in other countries. In this study, the two experimental food packaging systems (Torus Pak® and a Cryova Darfresh®) were both preferred by the elderly over the control. This study shows that the elderly has clear likes and dislikes around commodity packaging and that when offered packaging materials and systems that provide aspects of convenience, like ease of opening, they will clearly choose such systems.

This thesis offers a blueprint for establishing meal solutions for the elderly consumers. It is evident from Chapters 2, 3 and 5 that texture is a major determinant is establishing preferences in various age cohorts. Foods that are softer and easier to chew and swallow were favoured by the older age cohorts. Flavour differences among the varying age cohorts were noted from Chapters 4, 5, 7. Preferences for fat, fat replacers, salt and salt replacers were established. One very interesting discovery from this thesis is the decreased perception noted for salt perception in the 41-64 age cohort. This trend was evident in Chapters 5 & 7. Perhaps our attention should be directed towards monitoring sensory decline from the age of 40. This decline in salt perception may be the driving force behind the high consumption of salty foods and in turn problems with CVD. Chapter 4 does not demonstrate a decline in salt perception until after the age of 45. It may be possible that smaller age groupings should be used in the future to establish precise time points in salt deterioration.

Specific sensory changes and attributes was determined in Chapter 7 and applying these to the trained panel and consumers to develop the 'ideal' product in Chapter 8. Finally this 'ideal' sausage product was packaged using tailor made packaging for the elderly consumers, which was received by the ageing cohort extremely well.

Conclusion

The role of product development encompasses the problems, preferences and the ability of this age cohort. However, in Ireland currently there are no measures in place. ‘Wiltshire Farm Foods’ who deliver traditional meals to the aging consumer such as lamb stew, apple crumble and custard and an all-day breakfast consisting of sausages, rashers eggs and are a prime example of an innovative company acknowledging the need for traditional nutrious foods which cater for elderly consumer. More companies like this are needed to cater for this age cohort sdepleating nutritional staus. From this thesis, it is evident that the elderly consumers prefer traditional products. Measures like the ‘Wiltshire Farm Foods’ are greatly needed in Ireland, particularly in rural settings where shops and restaurants aren’t always readily accessible.

A cost-effective way of alleviating pressures on medical care is nutritional intervention. Nutrition intervention should start before the problem arises. Measures like protein fortification to help with the growing population of sarcopenic the elderly, increasing of certain flavours to combat non-appealing tasteless food due to decline in senses, dry mouth and alterations to taste due to various medications and reduction and replacement of fat, salt and sugar with other healthier alternatives are some starting points. A greater investment is required to study the need and adaptions for the elderly community. Government funding should focus on education, industry and research and place greater emphasis on life quality in our country. Older adults often subconsciously adapt to modified diets. This may manifest itself in not eating steak and other tough cuts of meat due to chewing difficulties on fearing that aspiration may occur. Not eating chicken due to a lack of flavour or only drinking instant soup due to its salty taste. This in turn will have a detrimental effect on food industry. With this growing population decreases in meat consumption may occur due to an aversion to meat and meat products because of aging. It is therefore critical from a health point of view and an industry point of view that this issue is tackled soon. As can be seen from this research meat packaging in Ireland needs to have greater focus and attention. Different mechanisms, various materials and aids should be explored to aid this population to live independently for as long as possible without causing harm or injury due to below standard food packaging. Careful planning and consideration should be incorporated into the marketing of products for the aging consumer. Consumers may not be inclined to purchase food products with the term ‘aging’ ‘the elderly’ or ‘older consumer’. A universal colour scheme may be introduced on food labels. For example, ‘yellow’ may be for consumers with mild swallowing difficulties, orange may be for those with moderate swallowing difficulties and red may be for older adults with severe swallowing difficulties. A multidisciplinary approach may be beneficial whereby Food Scientists, Nutritionists, Speech and Language Therapists, Doctors, Dieticians, Occupational Therapists Food Marketers and those involved in the Meat Industry work together to solve this public health crisis. Nutrition is a fundamental human right one we should may more attention to especially as our population is aging.

Of recent years attention has been focused on developing the growth and development of children. Infant formulas consisting of adequate nutrients for the growth and development of our babies, public health interventions such as the fortification of our breads with folic acid, the addition of fluoride to our water and the encouragement of school children to consume more fruit and vegetables through the 'Food Dudes' scheme. Children have abundant needs, however so too do the elderly. The elderly age cohort often is a neglected age group in society. The incidences of depression increase after retirement. The feeling of self-worth is often increased as this genre are often 'empty nesters' whereby their children have left home and are independent of their parents.

A total transition in food consumption is often noted in this age cohort. No longer are large weekly shops needed as two or even one-person households become common. Daily shopping often becomes the cause to partake in a social outing and to buy smaller amounts of food to prevent food spoilage. The need to encourage this age cohort to meet their daily nutrient requirement to prevent malnutrition is often overlooked. Adults of retirement age (>65 yrs. old) have many active years left thanks to advances in medical care and health knowledge. However, it is essential that society recognises the importance of maintaining the health of the 'young the elderly'.

Menopause, decline in the ability to taste and smell food, altered food preferences and aversions due to medication and the loss of ability to cook meals due to problems with mobility and dexterity are issues that should be considered when evaluating the ability of this age cohort to perform daily tasks independently.

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