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Discolouration complaints in minced meat. Do the food miles travelling affect the customer complaints?

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Discolouration complaints in minced meat. Do the food miles travelling affect the customer complaints?

By

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AUTHOR'S DECLARATION

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Doctoral College Quality Sub-Committee. Work submitted for this research degree at the University of Plymouth has not formed part of any other degree either at the University of Plymouth or at another establishment.

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Abstract

Meat discolouration is an area of significance to the meat processing industry since customers expect meat to have a bright red colour when purchased. Normally, when exposed to oxygen the myoglobin pigment in meat will give it this bright red colour as it is in the form of oxymyoglobin, but this may turn to the brown pigment metmyoglobin, and to prevent this meat is packed under a modified atmosphere containing a mix of carbon dioxide, oxygen and nitrogen.

The factory under consideration, Factory X, is located in the far SW of the UK and dispatches meat to depots across the UK. During the summer of 2013, a large volume of complaints of meat discolouration in fresh, minced beef was received and it was thought that this might be linked to distance travelled. Results showed that this was not the case as complaints were not higher in depots at the greatest distance from the factory, nor were the complaints linked to specific depots. The study also showed that discolouration was not related to the modified atmosphere packaging process nor was shelf life insufficient.

The study examined other factors that could influence meat discolouration and found that temperatures of product may exceed 8℃ on supermarkets' shelves and thus temperature abuse could be a significant factor. During shopping trips customers may have a time lag between the purchase of meat products and refrigerating them once home and the study concluded that this may be one of the main reasons for discolouration.

A factor of great importance to the meat industry that became apparent was the lack of adequate information about complaints from consumers to retailers and thence to the processor. This meant that it was not possible to perform complaint analysis and this then meant that a single cause could not be defined. It is recommended that a simple system be developed with the retailers for recording complaint details so that complete analysis can be performed.

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List of abbreviations and acronyms

BRC	British Retail Consortium
BSE	Bovine Spongiform Encephalopathies
CCP	Critical control Point
CO_2	Carbon Dioxide
CODEX	*Codex Alimentarius* – Food Code
CP	Control Point
EU	European Union
FBO	Food Business Operator
FIFO	First-in first-out
FSA	Food Standards Agency

FSAI	Food Standards Agency Ireland
GMP	Good Manufacturing Practices
HA	Hazard Analysis
HACCP	Hazard Analysis and Critical Control Point
ICMSF	International Commission on the Microbiological Safety of Foods
MAP	Modified Atmosphere Packaging
N_2	Nitrogen
NACMCF	National Advisory Committee on Microbiological Criteria of Foods
O_2	Oxygen
PRP	Pre-requisite programmes

Chapter 1

Introduction

This project was brought about in order to investigate complaints received by a meat processing plant, hereafter known as Factory X. The factory produces minced meat, burgers and kebabs from beef, lamb, and venison for a major retailer. Analysis of complaints sent from major retailers is an area of difficulty as these complaints rarely have any accompanying data and can affect the relationship between producer and retailer. This is a problem for factories supplying major retailers and this project hoped to establish some protocols that might either reduce complaint volume or might improve the analysis of complaints from supermarkets.

In 2013 Factory X received several complaints about minced meat discolouration. Discolouration complaints made up a total of 34.07% of complaints received during the period from week one to week 35 of 2013. This number revealed a high percentage of products being "rejected" at the final customer stage.

The amount of complaints received, the financial costs involved and the effect on reputation gave the site concern and a root cause analysis was to be put in place to prevent re-occurrence or at least a decrease in complaints of this nature. This project became one method of analysis of these complaints to help in reducing them. The original aim of this study was "to investigate whether the origin of discolouration in minced beef products was linked to the geographical location of complaints".

Factory X is located in the far southwest of the country and distributes products to many depots that are located all over the country – by grouping the complaints per depot and analysing the volume of product sent to that specific depot as well as the mileage travelled in between Factory X and the depot.

However, it soon became evident that the mileage travelled was not the cause of so many complaints. So in order to achieve the aim and to help in reducing the number of complaints new objectives were created:

- Through complaints analysis assess whether complaints are more frequent in some depots or stores. One of the hypotheses could be a failure related with a depot or store – by counting the number of complaints in a specific depot and by calculating the percentage of complaints in each depot using volumes of product sent to each one;
- Assess the effectiveness of the MAP system and the shelf life given by company – looking at the shelf-life results in order to ascertain if use by date given to the product was in compliance with a safe product and with no quality issues raised as discolouration;
- Ascertain if the shelf life is insufficient to avoid discolouration complaints;
- Establish potential temperature abuse throughout the supply chain including at the customer end of the chain.

During this study and in order to achieve the aim, some other methodologies were introduced. Due to temperature abuse fresh produce can became discoloured and can show a significant growth of bacteria. It became crucial to do some temperature comparisons in some minced products experiments at some of the major retailers.

It was also decided to create a questionnaire focused on customer behaviour when shopping fresh products and at home. The purpose of the questionnaire was to allow assessing and connecting customer behaviour, with temperature abuse and discolouration issues.

Further temperature experiments were performed at home (mirroring customer behaviour) to judge the effect of temperature in discolouration.

This thesis reviews the causes of colour change in meat and discusses the possible association between growth of spoilage microorganisms and potential pathogen growth. The processing methods for the fresh meat products under investigation are reviewed and the mechanics of modified atmosphere packaging discussed. The investigation initially studied the link between miles travelled and complaints before examining other factors that could affect the discolouration process, as described above. In concluding the thesis, a possible model is suggested in order to enable better analysis of complaints.

Chapter 2

Review of Related Literature

<u>Background:</u>

1. <u>The product itself</u>

Minced meat is a food product of animal origin, which contributes valuable animal proteins to the diet of humans and therefore is not for vegan or vegetarian people. Minced beef is considered by many to be the most popular and most versatile of all beef products. The modern life style affects people's life in a way which compromises free time and family time. Time to prepare healthy foods after long working hours becomes a scarcity. That is why minced meat has become so common; there are plenty of recipes which involve this product. Some of them are really popular and easy to do; and that is the reason why minced meat is enjoyed by young and old alike. The key to the continuing popularity of minced beef lies in both its recognized consistency as an enjoyable and economical food by consumers, as well as the foodservice industry's ability to prepare, handle and serve minced meat products in a safe and easy manner.

Complaints indicate the level of customer satisfaction. Dissatisfaction can lead to a loss of consumer confidence, a fall in sales and may lead to the loss of the supplier contract with customers. This, in turn, may lead to unemployment in both the processing and supplier industries. Factory X prides itself on providing a professional, competitive and friendly service to the farming businesses which supply it with quality livestock. So, the factories located in the South West are extremely important with respect to the social and economic importance to the region, either by the large number of workers it employs or by established contact with local producers. Helping to maintain and enhance the sustainable production of beef and lamb in this area is a key consideration for the company. The retailer concerned is one of the major supermarkets in this country and is always trying to improve the quality standards of their products and this has a reflection on the final price. Thus, the tolerance of the customer for the failures in the quality of the products purchased at this supermarket decreases.

Factory X is responsible for the production of a large variety of products using beef, lamb or venison meat. Those products are hamburgers, meatballs, kebabs or minced beef and lamb. Due to the nature of the final products some of them are produced with the addition of spices whilst some are without. Neither minced beef, nor minced lamb, contain any other added ingredients. However, in products such as burgers, kebabs or meatballs the recipe always requires some kind of spice added. Spices may have certain antimicrobial and antioxidant properties through which they can contribute to the quality of the product (Velasco and Williams, 2011). Thus, minced meat may be susceptible to a discolouration process faster than products made with the inclusion of spices, and this is reflected in the product shelf life. Whilst factory X produces such a diverse range of meat products, this investigation will focus in the production of minced meat, because this product is more susceptible to claims for discolouration and in particular it will focus on beef products since the production of minced lamb meat represents a small percentage of the total volume of production.

According to the website of the European Commission (http://ec.europa.eu/food/animal/animalproducts/meatproducts/minced_meat_en.htm

) minced meat is defined as boned meat that has been minced into fragments and contains less than 1 % salt. The authority explains that minced meat must have been prepared exclusively from skeletal muscle (including adherent fatty tissues) that complies with the requirements for fresh meat; in other words minced meat is produced with muscle meat and fat. Some of the primal cuts frequently used on this process (minced meat, burgers, meatballs) are chuck, visual lean (VL) trim, flank, leg of mutton cut (LMC), brisket.

Processed meat products may include various different types and local or regional variations; in other words there are a considerable number of claims regarding product authenticity and product origin which may affect product quality, labelling information and marketing campaigns. That is why at the supermarket's shelves, the customer will find Irish minced meat, Scottish minced meat, Welsh minced meat, British minced meat. That is also why finest meat or organic products can also be purchased. The criteria most used to assess this "quality" factor are the organoleptic evaluation and consumer preferences and thus customers may be more demanding of aspects such as meat colour. There are for example some local breeds such as Aberdeen Angus or Welsh Black, and consumers usually tend to add value to its meat and consequently adding value to the product being reflected on the final price. Claims are therefore a requirement to be complied with to ensure authenticity is preserved.

2. HACCP

In any food industry the Hazard Analysis and Critical Control Point (HACCP) technique is increasingly being applied to the safe production of food. Customers have an underlying implicit understanding that food is safe to eat. HACCP is based on a common-sense application of technical and scientific principles to the food production process from farm to fork.

The most basic concept underlying HACCP is that of prevention rather than inspection (Gill, 1998). A food grower, processor, handler, distributor or consumer should have sufficient information concerning the food and the related procedures they are using so that they will be able to identify where a food safety problem will occur and how it will occur. If the "where" and "how" are known, prevention becomes easy and obvious and finished product inspection and testing superfluous. The objective is to make the product safely and to be able to prove that the product has been made safely (Gill, 1998). The “where” and “how” are the Hazard Analysis (HA) parts of HACCP. The proof of the control of the processes and conditions is the Critical Control Point (CCP). Applying this basic concept, HACCP is simply a methodical and systematic application of the appropriate science and technology to plan, control and document the safe production of foods free from any hazards (physical, chemical, biological and allergenic).

The HACCP concept was first developed in the 1960s during the initial stages of the US space program. Recognising the potentially catastrophic consequences of food borne illness among astronauts during missions in space, scientists from NASA and the food processing industry reviewed the then-existing methods for ensuring the microbiological safety of foods. The methods, consisting primarily of end product testing, were inadequate for providing 100 percent assurance that the foods prepared for the astronauts were safe. As a result a new procedure was developed to control food safety over the entire production process. By identifying all the points in the production and distribution process that were critical to food safety, and implementing appropriate controls, food safety could be assured with nearly 100 percent confidence and without the need for extensive testing of finished product.

The concept has been refined and developed by such bodies as CODEX, the National Advisory committee on Microbiological Criteria for Foods (NACMCF) and The International Commission on the Microbiological Safety of Foods (ICMSF). A major refinement has been the inclusion of pre-requisite programmes (PRP) which are defined as “universal steps or procedures that control the operational conditions within a food establishment assuring environmental conditions that are favourable to the production of safe food” (FSA, 2013).

The importance of a PRP cannot be overstated: they are the foundation of the HACCP plan and must be adequate and effective. They have reduced the complexity of many HACCP plans by including common fundamental processes.

EU states that “Where the prerequisite requirements (whether or not supplemented with guides to good practices) achieve the objective of controlling hazards in food, it should be considered, based on the principle of proportionality, that the obligations laid down under the food hygiene rules have been met and that there is no need to proceed with the obligation to put in place, implement and maintain a permanent procedure based on the HACCP principles." (EC NO 1955/2005).

The common prerequisite areas include:

1 – Cleaning

2 - Glass / Hard plastic checks

3 – Calibration

4 - Maintenance Programs for Equipment and Buildings

5 - Management Commitment

6 - Purchasing Packaging

7 - Pest Control

8 - Personal Hygiene

9 - Storage, distribution & transport

10 – Staff Training

11 – Traceability

12 – Refrigeration

13 – Waste

14 – Water

15 - Allergens Control

16 -Process to prevent cross contamination

HACCP covers all types of potential food safety hazards - biological, physical, allergens and chemical. Microbiological hazards however are the most serious from a public health perspective. For this reason, while HACCP addresses all four types of hazards, a majority of the emphasis is placed on microbiological issues (Gill, 1998).

The primary goal of applying HACCP principles for the plant operations therefore is to prevent, eliminate, or reduce the incidence of microorganisms pathogenic to humans. The live animal is exposed to a variety of potential sources of microorganisms e.g. soil, water, feed etc. and often acquires pathogenic microorganisms initially as a result of exposure on the farm or during transport and indeed the source can be the animal's natural flora, which is harmless to the animal but may end up on the meat. In healthy animals, microorganisms are confined primarily to the gastrointestinal tract and exterior surfaces (hooves, hide and hair). During slaughtering and dressing, the surface of the carcass may become contaminated with these microorganisms (Gill, 1998). Foods of animal origin may also be contaminated by microorganisms persisting in the processing environment, or as a result of contact with food handling personnel or equipment during processing, distribution, retailing and use. The extent of this contamination will depend to a large extent on the sanitary control exerted during slaughtering and dressing (Gill, 1998; FSA, 2013).

The HACCP plan is the optimal means for food safety management. Management's commitment to the HACCP concept is imperative for successful implementation including the communication of this concept among all levels of plant operations and management.

The General Hygiene Requirements for all food business operators are laid down in EU Regulation 852/2004. EU Regulation 853/2004 supplements EU Regulation 854/2004 in that it lays down specific requirements for food businesses dealing with foods of animal origin. Regulation 854/2004 relates to the organisation of official controls on products of animal origin intended for human consumption. This legislation promotes the production of Industry Guides for the application of Good Hygienic Practice and HACCP Principles. After consultation with all Industry stakeholders, the FSA issued its Guide to Food Safety & other Regulations for the UK Meat Industry at the end of 2006 and the most up to date version can be viewed on the FSA website (FSA, 2016). This Regulation is supplemented by Commission Guidance Document No. 1955/2005 on the Implementation of Procedures based on the HACCP Principles, and on the facilitation of the implementation of the HACCP Principles in certain food businesses. This Guidance Document emphasises that Food Business Operators are allowed maximum possible flexibility when establishing food safety management systems based on HACCP principles, for the operations under their control.

A central pillar of the entire EU Hygiene Package is that the Food Business Operator (FBO) has primary responsibility for ensuring the safety of the foodstuffs they produce. Accordingly, the legislation attempts to establish certain Food Safety Objectives which the FBO must achieve, whilst allowing the FBO to decide precisely how this is best done in their particular operations.

The General Food Law legislation, (EC NO 178/2002) introduces the principle that when determining whether any food is unsafe, regard must be taken of the normal conditions of use of a food by the consumer, and information provided to the consumer, including information on the label, and other information generally available to the consumer.

All of the above mentioned regulations are to be used in conjunction with EC NO 1069/2009 which lays down health rules as regards to animal by-products and derived products not intended for human consumption. Animal by-products not intended for human consumption are a potential source of risks to public and animal health. Past crises related to outbreaks of foot-and-mouth disease, the spread of transmissible spongiform encephalopathies such as bovine spongiform encephalopathy (BSE) and the occurrence of dioxins in feeding stuffs have shown the consequences of the improper use of certain animal by-products for public and animal health, the safety of the food and feed chain and consumer confidence (EC NO 1069/2009). As part of the complete recasting of all EU Food Hygiene Legislation the EU has also published Microbiological Criteria for Foodstuffs (EC NO 2073/2005), which are divided into (i) Process Hygiene Criteria and (ii) Food Safety Criteria.

HACCP is the tool that allows the food business to cover all types of potential food safety hazards - biological, physical, allergens and chemical. Microbiological hazards however are the most serious from a public health perspective. For this reason, while HACCP addresses all four types of hazards, a majority of the emphasis is placed on microbiological issues.

Causes of discolouration

Meat discolouration can be caused by many factors such as temperature abuse, oxidation, lipid oxidation/spoilage, light exposure, microbial growth, age of the animal, feeding and seasonal influences and storage conditions. For example, as animals get older the composition of muscles start to change regardless of the species or sex (Hoffman and Fisher, 2001). An increase in animal age leads to a decrease in meat tenderness, an increase in connective tissue content and an increase in intramuscular fat, saturation of intramuscular lipids and myoglobin concentration (Lawrie, 1998;

Hoffman & Fisher, 2001). The connective tissue of young animals has less cross bonding and with age the chemical composition (solubility) of connective tissue changes whereby it decreases (Lawrie, 1998).

When in the healthy animal, meat is sterile due to the animal's immune system and any possible microbial contamination is only found in the carcass and externally. Jay (1992) described the sequence of events that take place post-slaughter and the microbial scavenging process ceases after several hours at which point microorganisms can grow unchecked. When cut, surfaces exposed to the air are ideal for the growth of most bacteria. Minced meat, because of its large exposed surface area, facilitates spoilage which may cause discolouration, and thus those products have a limited shelf life (Degirmencioglu *et al.,* 2012). However, as this context refers to a factory environment it is crucial that some basic considerations are addressed in this initial phase.

Despite the importance of microorganisms in food spoilage, the definition and assessment of spoilage relies on sensory evaluation. This means this concept is a subjective judgment by the consumer which may be influenced by several variables such as cultural or economic. The judgment is influenced by considerations and customer background as well as by the sensory acuity of the individual and the intensity of the change. When spoilage progresses most consumers would agree that gross discolouration, strong off-odour are reasons enough to reject the product. However, spoilage is characterised by any change in a food product that renders it unacceptable to the consumer from a sensory point of view. This may be physical damage, chemical changes (oxidation, colour changes) or appearance of off-flavours and off-odours resulting from microbial growth and metabolism in the product. Microbial spoilage is by far the most common cause of spoilage and may manifest itself as visible growth (slime, colonies), as textural changes (degradation of polymers) or as off-odours and off-flavours (Nichas *et al.,* 2007).

To prevent food discolouration and subsequent food spoilage at the production stage it is essential that food safety is ensured at all phases of production. Food safety is the absence of any risk of harm from food. Generally speaking, food safety describes the practice of managing food in such a way that the food is highly unlikely to cause any harmful effects, whether in the short term or long term, to anyone who consumes products that have been processed, stored or sold by the business. Food hygiene can be considered as the practical process of ensuring that food is fit to eat.

There will always be food safety hazards, but they can be controlled if food handlers understand how food becomes contaminated and how to prevent this from happening. Contamination is the transference of any objectionable or harmful substance or material to food. There are three types of contamination that can potentially affect anyone: microbial (also referred to as microbiological contamination and contaminants include food poisoning bacteria, spoilage bacteria, moulds, yeasts); physical (contaminants include glass, wood, hair, polythene, dead insects, metal fragments); chemical (contaminants include cleaning material, pesticide residues, perfume). Allergenic contamination can be considered as a fourth factor due to its particularity (Nash and Stevenson, 2011) however in most cases is include together with chemical contamination. Discolouration can be caused by microbial contamination when the spoilage bacteria break down protein, causing spoilage or putrefaction that may be detectable by smell or colour but does not usually cause food poisoning.

In order to control the discolouration of minced meat, the manufacturer needs to have a strong pre-requisites programme in place, implement a robust Hazard Analysis and Critical Control Point plan, and follow quality procedures. In other words the business must follow a correct training programme where employees are trained in food safety, understand the importance of their roles in producing safe product but also what to do to promote the quality of the product, know and follow the specifications and know how to act / react when the product falls outside the parameters. Staff monitoring critical control points (CCP's) have specific training and know what corrective actions to take. The business conducts a strong HACCP plan identifying potential hazardous to the product, establishing critical control points, implementing and monitoring controls.

In order to implement an HACCP plan that works effectively it is crucial to have monitoring procedures in place. Food plants have to ensure that the procedures laid down in the relevant Procedures Manuals are carried out at all times. In order to achieve this objective all processes are governed by HACCP plans which point out any hazards which may occur within the process and how they are dealt with.

If any step of a HACCP is showing non-conformances, corrective actions have to be implemented. Safety is improved by the prevention of potential causes and elimination of actual causes of non-conformance and the initiation of preventative and corrective action. A non-conformance is any deviation from the required standards during the production process. Records are maintained for all steps in the application of the

HACCP Principles. This includes each CCP, where relevant and all general controls. Record keeping provides evidence of food safety and also provides documentation for audits. In addition it is a tool for personnel training and solving problems (FSA, 2013).

In order to maintain the HAACP plan working effectively the food business has to verify the sum of activities other than monitoring that determines the validity & compliance with the HACCP programme. Commonly utilised are: analysis of daily checks and monitoring records; structured internal audits & higher level audits; microbial analysis of samples which are trended for easy interpretation; analysis of customer complaints & feedback; analysis of customer audits.

In order to understand the problem posed to factory X it is crucial to review the following: bacterial contamination, Modified Atmosphere Packaging, Shelf-life and temperature control.

<u>Bacterial Contamination</u>

Bacterial contamination is one of the types of contamination that can be introduced and if not controlled growth of bacteria can lead to unsafe levels at the point of consumption. The factors affecting bacterial growth can be summarised as temperature, pH, $a_{w,}$ gaseous environments and nutrients. In addition to these, many consider time to be a factor and so in this case, one can consider shelf life as this factor (Nash and Stevenson, 2011).

Beef muscle is a nutrient rich substrate that can support the growth of a wide range of microorganisms. It is generally accepted that the interior of intact muscle is free of microorganisms (Institute of Food Technologists, undated). However, localised presence of bacteria can occur in lymph nodes or the area adjacent to bone joints, particularly if they are inflamed. Microorganisms are introduced into the interior of meats as a result of the translocation of bacteria from the surface of the carcase. The initial micro flora is diverse at the time of slaughter; however, subsequent refrigerated storage selects for a limited group of aerobic species. The specific genus encountered is dependent on the storage temperatures, oxygen availability and moisture content. These are some of the factors, which have to be considered when carrying out a hazard analysis of the slaughtering operations (FSA 2016).

Red meat primary processing plants produce raw meat which, it is acknowledged, is not sterile and which may be contaminated with harmful organisms. Indeed, in the classical HACCP sense there is a subsequent step in the process which will eliminate this hazard i.e. cooking and it could be argued that there is no Critical Control Point (CCP) in existing primary processing plants (FSAI, 2002; FSAI, 2007).

Factors affecting the growth of microorganisms:

Temperature: Microbial growth is strongly dependent on environmental temperature. As storage temperatures are lowered towards freezing there is a significant decrease in the rate of microbial growth as well as a reduction in the diversity of the micro flora. Temperature control at each processing stage, where possible, must therefore be considered when controlling the microbial hazards of beef (Nash and Stevenson, 2011).

Moisture Content: Fresh meat has a water activity (a_w) of >/= 0.99 which supports the growth of a wide variety of bacteria, yeast and moulds. At high a_w values (a_w > 0.97) the rapid growth rates characteristic of bacteria allows them to predominate (Safe Food 360º, 2014). However as meat surfaces become dry, the differential in growth rates between bacteria and fungi becomes less important. A proper chilling regime with beef properly spaced to allow excess moisture to be evaporated must be a considered. Condensation must be avoided with adequate ventilation as this could lead to localised area of high a_w (USDA/FSIS 2011).

Oxygen Availability: Unpacked fresh beef represents two distinct microbiological environments in relation to oxygen availability. The surface is aerobic, an environment which permits the rapid growth of aerobic psychrotrophs such as *Pseudomonas*. However, an anaerobic environment predominates within 2 mm of the surface (Lawrie, 1998). This supports the growth of anaerobes, microaerophiles and facultative anaerobes. Restricting oxygen availability through the use of physical barriers can substantially alter the microbial growth at the surface of meats. Fresh beef is an actively respiring system and even a partial restriction of oxygen permeability across plastic wrap results in a depletion of oxygen and an accompanying increase in carbon dioxide (USDA/FSIS 2011).

pH: The pH of fresh beef is dependent on a number of factors including feeding, and handling practices at the time of slaughter and range from pH 5.3 - 6.5. Under normal conditions, the pH of beef after slaughtering and chilling is < 5.8. Both the rate of microbial growth and the diversity of the microflora will be restricted at the lower end of the pH range (Garcia-Lopez *et al.,* 1998).

As per report on *Emerging Microbiological Food safety Issues*, there are different microorganisms associated with food poisoning and food borne illness (Institute of Food Technologists). Some characteristics of specific pathogenic microorganisms are as follows:

***Campylobacter* spp.**

Campylobacter species have been implicated in outbreaks of food borne illness. Pigs, cattle, sheep, birds, dogs, cats and other pets can be reservoirs of infection and therefore raw meat is high risk with respect to this organism. It can survive vacuum packing but is destroyed by thorough cooking. Temperature range for growth is 28-45°C; all species grow at 37°C but they do not grow below 28°C. The species will persist in chill and frozen conditions (FSA, 2016; USDA/FSIS 2011).

Clostridium botulinum

This organism is found in the soil and aquatic environments as well as the intestinal tract of animals and fish. Food poisoning occurs when the spores of *Clostridium botulinum* have germinated in a foodstuff and the bacteria then grow and produce toxin that is consumed when food is eaten. The spores are very heat resistant so a temperature of 121°C for three minutes is required to destroy them. Outbreaks have involved inadequately cooked canned products, or damaged cans. There are no historical instances of it affecting unprocessed, fresh vacuum packed beef, however, inadequately processed low-acid foods and vacuum-packed products have been implicated. Temperature range for growth is about 3°-50°C, with an optimum between 20°-30°C (USDA/FSIS 2011).

Clostridium perfringens

This organism is found everywhere in the environment: in soil, the gut of man and animals. These organisms form spores which are resistant to heat. They can be transmitted by eating contaminated food, usually stews and curries, gravies that have not been properly heated or re-heated. It is not considered to be an issue in uncooked food but could be an issue if this meat is subsequently used for these types of food by the consumer. Spores are very likely to revert to live, vegetative bacteria and multiply during slow cooking and re-heating. Temperature range for growth is about 20°-50°C, with an optimum between 37°- 45°C (USDA/FSIS 2011).

Escherichia coli

There are several strains of *E.coli* classified by groups. The most significant group is that containing the haemorrhagic strains of *E.coli*. Many produce a toxin called a verocytotoxin and these are known as VTEC, the most common being *E.coli* O157:H7 (Doyle, 1991). Entero haemorrhagic *E.coli* is an important cause of both haemorrhagic colitis and haemolytic uraemic syndrome. The latter is the most common cause of acute kidney failure in children. *E.coli* lives in the intestines of cattle and can contaminate meat during slaughter and dressing (USDA/FSIS 2011). Temperature range for growth - growth can occur at 7°-44.5°C, and possibly as low as 4°C with an optimum for VTEC around 37°C. Acid tolerant, it will persist in frozen and chill conditions. *E. coli* 0157 is of great concern to the meat industry due to its virulence (Doyle, 1991).

Listeria monocytogenes

Widely distributed in the environment in soil, foliage, water and sewage*, Listeria* can be excreted by human and animal carriers. Any product of animal origin can harbour the bacterium. Often found in chilled or delicatessen products such as soft cheeses, paté, cook-chill meals and ready to eat sausages. A low temperature, salt tolerant pathogen, this poses special problems for food handling and storage as standard refrigeration will not inhibit growth and the cells can survive for long periods even in unfavourable conditions. The organism can become established in food production environments surviving in biofilms in areas such as drains, foot baths and on surfaces. – Growth can occur as low as 1°C and up to 42°C and so is of importance in low-temperature foods (Whitley *et al.,* 1999).

Salmonella spp.

Salmonellosis is a major cause of food borne human gastroenteritis. The organism is found widely in the environment and in the gut of animals and man. Farm animals, wild birds and domestic pets are common reservoirs. Infection is most commonly associated with the consumption of meat (especially poultry and pork) and eggs and their products. Contamination commonly results from raw food coming into contact with ready-to-eat products. Temperature range for growth is between 6°-45°C (Nash and Stevenson, 2011).

Staphylococcus aureus

The organism is found on man, in cuts, pimples, boils, sores, on the hands and in the nose. Cows with infected udders also carry the organism. This bacterium is transmitted to food by contaminated hands or equipment or to milk from infected cows (Gill, 1998). A heat resistant toxin forms in the food at ambient temperature following growth of the bacteria. Illness is caused by ingestion of the toxin. Severity of illness may depend on how much toxin has developed. Temperature range for growth is usually between 7°-48°C with toxin being produced at between 10°-46°C (Nash and Stevenson, 2011).

Yersinia enterocolitica

Many members of the genus can grow under extremes of temperature and are well adapted to survive in the environment. Found in the guts of many species of wild and domestic animals and birds. It is transmitted by contaminated food and water and direct contact with infected animals. Person to person spread may occur. It is particularly associated with raw pork and pork products. Temperature range for growth is 0°-44°C with an optimum range of 32°-34°C (FSA 2016).

Whilst meat discolouration is not generally considered to be related to any of the above microorganisms, its presence could indicate high levels of microorganisms and thus the bacteria discussed could be present in a community.

In general, red meat processing plants do not operate any production step which eliminates microbiological hazards. Primary sites may not introduce a specific step to even reduce these hazards to an acceptable level. However temperature control is often considered a CCP or a Control Point (CP) due to its importance controlling and reducing the growth of bacteria. However despite this fact the tried and tested HACCP principles can and should be successfully adapted and applied to this sector. Because business cannot legislate who will consume the product produced, we therefore have to assume that vulnerable groups in society such as the very young, very old and those with weakened immune systems may consume the product.

On the Factory X site there is an intake quality control process which is a critical control point. Any incoming product must be checked to ensure it meets all the legal requirements, food safety and quality of product but also customer specifications and traceability. Temperature checks are undertaken to ensure temperatures are under the legal limits. Visual checks made to the product, against customer specifications, to ensure it contains no visible bones or foreign material, no bruises and that it does not have an off odour. Raw materials are routinely tested for the presence of pathogens and other bacteria, and samples may be taken to estimate its composition (lean-to-fat ratio). The beef is normally stored under the same state of refrigeration in which it was received, until it is ready for grinding on a “First-In/First-Out” (FIFO) rotational basis.

<u>Storage and Temperature conditions</u>

The main hypothesis to explain the discolouration complaints in this study is related to transportation and storage conditions. Factory X is located at one end of the country and all this minced meat is destined for the retailer’s depots all over the country including Northern Ireland and Scotland. However this is a very critical hypothesis because in theory that hypothesis should not take place for a few reasons. First of all meat cannot be sold after the use by date, so it should not matter how many miles the product travelled until it reached the final customer because:

- Transportation is operated by refrigerated lorries with temperature control;
- Professional people are taking care of the storage conditions;

- Depots and supermarkets are run by managers who should assure the conditions to keep the products with high standards of quality.

Thus if any relationship between complaints and food miles travelling is found, the reason may be in a failure of one of those aspects.

Meat is recognized as one of the most perishable foods. This is due to its chemical composition that favours microbial growth to unacceptable levels contributing significantly to meat deterioration or spoilage. When large numbers of microorganisms are present in raw meat, there will be changes such that it becomes unappealing and unsuitable for human consumption. The spoilage of raw meat is mainly due to undesired microbial development in meat during storage. The type of bacteria and their loads depend on the initial meat contamination and on the specific storage conditions that can influence the development of different spoilage-related microbial populations thus affecting the type and rate of the spoilage process (Doulgeraki *et al.,* 2012).

Food must be stored to ensure adequate supply and to prevent fluctuations in supply and demand. The correct storage conditions are essential for a hygienic and efficient food business because the rate of food spoilage is affected by temperature, humidity, stock rotation practices and the integrity of the packaging.

Storage temperature is considered the most important factor affecting meat spoilage by affecting the duration of the lag phase and the rate of bacterial growth. The lag phase is that period between initial contamination (inoculation) and the log phase where growth is exponential (Jay, 1992). Both storage time and packaging have a strong effect on the bacterial communities in chilled beef (Doulgeraki *et al.,* 2012).

At the factory, ambient temperature in production areas must not be higher than 8ºC; at the point of production meat temperature should not be above 3ºC, and immediately after packaging and labelling process the product is placed in despatch areas where temperature is always under 2ºC. Transportation temperature should also be less than 2ºC. These temperature requirements all form part of the PRP of the HACCP programme. Obviously all the temperature conditions at Factory X are in accordance with legislative standards.

EC Regulation 852/2004 contains a general requirement for temperature control, as set out in Annex II, Chapter IX, 5:

Raw materials, ingredients, intermediate products and finished products likely to support the reproduction of pathogenic micro-organisms or the formation of toxins are not to be kept at temperatures that might result in a risk to health. The cold chain is not to be interrupted. However, limited periods outside temperature control are permitted, to accommodate the practicalities of handling during preparation, transport, storage, display and service of food, provided that it does not result in a risk to health... (FSA, 2007).

Paragraph 12 in the Guidance on Temperature Control Legislation in the United Kingdom states: *the temperature of a food may "result in a risk to health" where temperature control is critical to the safety of food.* And paragraph 24 and 27 explain that *Schedule 4 (Temperature Control Requirements) of the 2006 Food Hygiene*

Regulations requires that in England, Wales and Northern Ireland, foods which are likely to support the growth of pathogenic micro-organisms or the formation of toxins, be held at or below 8°C, or, at or above 63°C. The Schedule allows certain exemptions from the requirements (consistent with the need to ensure food safety) to take into account practical considerations relating, for example, to processing or handling (…) The requirement applies to foods, including raw materials and ingredients, at all stages of preparation, processing, transport, storage and display for sale within the manufacture, retail and catering sectors (FSA, 2007)

<u>Shelf Life</u>

According to Sewald and DeVries (2015) in a study developed about food product shelf-life, the shelf life determines the length of time that a product will retain certain qualities including acceptable microbial counts, taste, appearance, vitamin levels and odour. The shelf-life analysis allows the determination of the best before or use by date of the product. Generally, food is considered to be past its shelf-life when it is no longer acceptable to the consumer. On one hand it could be that the colour, flavour, texture, aroma or nutrient content have deteriorated to the point where the food is no longer acceptable; on the other hand it could be when a food-safety issue arises (Laury *et al.*, 2006).

Whilst shelf-life is usually equated with spoilage, for fresh meat in particular, the end of shelf-life might be reached before spoilage, as such, is evident. For example, the loss of bloom of mince or steaks, or reaching a microbial count specified as an acceptable maximum by a retailer, may be the determinant of retail shelf-life; whereas spoilage, as defined by off-odour and slime, would be the point at which it is unacceptable for consumption (Nychas *et al.*, 2008).

Brown and Williams (2003) explained that the shelf-life of a product is best determined as a part of the product development cycle. This means the packaging technique plays an important role as it may be one of the means by which shelf life limiting processes are controlled, or the packaging per se may limit the product shelf life, that is why it is so crucial considerate packaging requirements for the product early during product development. According Brown and Williams (2003) shelf life testing is carried out by holding representative samples of the final product under conditions likely to mimic those that the product will encounter from manufacture to consumption. It is also common to try to simulate adverse or abusive conditions. It will allow developing a more comprehensive knowledge and understanding of the different reactions of the product in abusive conditions, such as temperature or storage conditions.

Once the microbiological safety of the product has been determined, quality issues can be considered. This may be based on microbial numbers, chemical specifications or sensory assessment. In most cases it is likely to be a combination of these. As Brown and Williams (2003) described, in the European Union, shelf life is not defined in law, nor is there legislation regarding how shelf life should be determined. According to Directive 92/59/EEC on general product safety, the manufacturer is responsible only for placing safe products on the market. The EU Directive on food labelling (79/112/EEC) requires pre-packaged foods to bear a date of minimum durability (best before or best before end) or, for highly perishable foods from a microbiological point of view, a use by date. This date is defined as ‘the date until which the foodstuff retains its specific properties when properly stored'. This date (and therefore the shelf life) is fixed under the producer's responsibility.

The decision as to whether a food requires a use by or best before indication rests with those responsible for labelling the food, since they are in the best position to assess its properties. The objective of most shelf life testing is to determine how rapidly microbiological, chemical and physical changes occur in the food during distribution and storage. Since different storage conditions accelerate some changes but not others, it helps to know before testing what changes are likely to occur. The shelf life determination allows any company to set a use-by-date and/or best-before date. The microbiological safety and stability of a food product is measured by its shelf-life, these important factors are influenced by storage conditions, time and temperature. However it is important to keep in mind that in reality products' deterioration starts for most manufactured foods before they are packaged. Fortunately, the rate of deterioration in many foods is slow; hence, they can be stored for some time before they become unacceptable or significantly deteriorated. The change of quality over time is a function of storage temperature, humidity, package protection, product composition, water activity, processing conditions, and ingredient quality.

Modified atmosphere packaging

Modified atmosphere packaging (MAP) is a technique used to extend the shelf life of fresh food. It works by surrounding the food with gases that stop, or at least slow down the growth of bacteria, yeasts and moulds that spoil food. Without these microbes, meat can be kept for longer periods of time and will take longer to spoil, or may age at a slower rate. Meats packaged this way are commonly safe because the growth of pathogens is inhibited. However MAP does not completely eliminate pathogens, and without spoilage microbes, there are fewer obvious signs of deterioration (e.g., it smells ‘off’ or is discoloured) to indicate the meat may be unsafe to eat (Mullan and McDowell, 2003; Degirmencioglu *et al.*, 2012).

The technology substitutes the atmospheric air inside a package with a protective gas mix (Oxygen (O_2), Carbon Dioxide (CO_2) and Nitrogen (N_2). The gas in the package helps ensure that the product will stay fresh for as long as possible. The combination and percentage of gases will depend on the product but is used on minced products to mainly to perform the control of chemical, enzymatic and microbiological reactions; to reduce degradation produced during the storage period; retain the fresh character of the products, maintaining the attractive red colour; increasing the shelf life and reducing spoilage; ant to prevents rancidity caused by oxidation (Mancini and Hunt, 2005).

The gases used are oxygen, carbon dioxide and nitrogen. Each gas plays a crucial role in this technique. Oxygen is the condition for the growth of aerobic microorganisms and in general must be excluded from the MAP however beef products are an exception as myoglobin is present in the muscles; the interaction of myoglobin with O_2 is responsible for the meat colour. Carbon Dioxide inhibits the increase of most aerobic bacteria; the higher the concentration the longer the durability of the perishable product; anaerobic bacteria respiration increase with CO_2 which can lead to spoilage yet spoilage is controlled by the shelf-life – Use by date. Nitrogen is an inert gas used to expel air especially O_2 out of the packaging; it is also used as a filling gas which equalises the effect of CO_2 absorption by the perishable food; reduces the vacuum effect (Dansensor, 2012).

Meat colour depends on the amount of and the state of myoglobin. Myoglobin is the protein with the major influence in meat colour. Myoglobin (Mb) is a globular protein of vertebrates. It is one of the simplest proteins that transport molecular oxygen (O_2), the main intracellular carrier of oxygen in muscle tissues, as well as storing oxygen in the muscles. The main function of myoglobin is as a reserve of oxygen in muscles of mammals. The red colour and the abundance of myoglobin in certain muscles or in certain species explain the difference in appearance between white meat and red meat (Mancini and Hunt, 2005). This is visually explained in the image below.

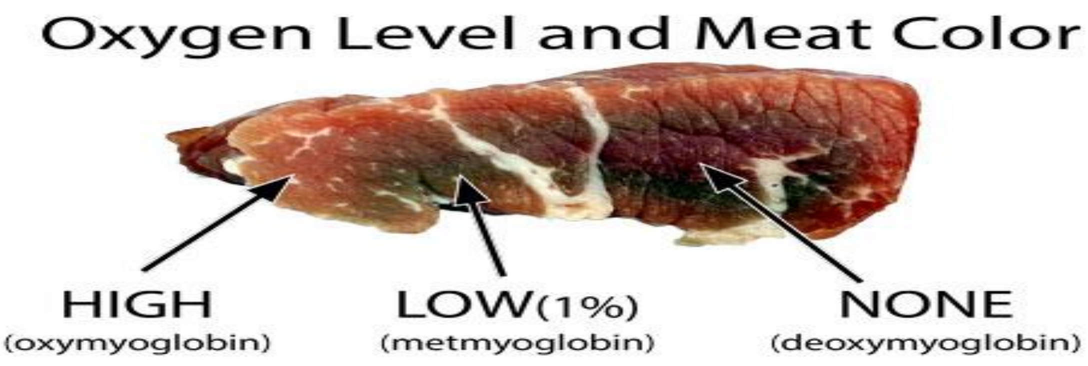

Figure 1: Oxygen level and meat colour (Blonder 2014)

Myoglobin is the principal pigment of fresh meat, which can exist in three main forms. Deoxymyoglobin is the deoxygenated form and is responsible for the purple colour of freshly cut meat or meat stored in the absence of oxygen, such as with vacuum packaged meat. When exposed to oxygen, deoxymyoglobin is rapidly transformed into oxymyoglobin. This form of myoglobin is responsible for the attractive bright red colour of meat typically associated with freshness by consumers. The third form, metmyoglobin, is brown and is irreversibly formed through the oxidation of myoglobin (MIS, 2001). Consumers relate the presence of this brown colour to the loss of freshness and are reluctant to purchase that particular product. Final meat colour is determined by the relative proportions of the three forms of myoglobin present at the surface of the meat.

The colour of meat is the index of freshness and quality obvious to the consumer and it is determined by the relative proportion of the three forms of myoglobin as previously discussed.

During prolonged storage, oxymyoglobin is oxidized to metmyoglobin which gives the meat the unattractive brown colour. While oxygen is necessary to maintain oxymyoglobin in fresh beef, it also promotes lipid oxidation which can lead to flavour defects (Mancini and Hunt, 2005).

Very low oxygen tension is required to maintain myoglobin in a deoxygenated state. ‘Oxygenation occurs when myoglobin is exposed to oxygen and is characterized by the development of a bright cherry-red colour. As exposure to oxygen increases, the oxymyoglobin penetrates deeper beneath the meats surface. The depth of oxygen penetration and thickness of the oxymyoglobin layer depend on the meat’s temperature, oxygen partial pressure, pH, and competition for oxygen by other respiratory processes’ (Mancini and Hunt 2005).

Figure 2 illustrates the effect of oxygen on meat pigments and the relationship between meat colour and these pigments.

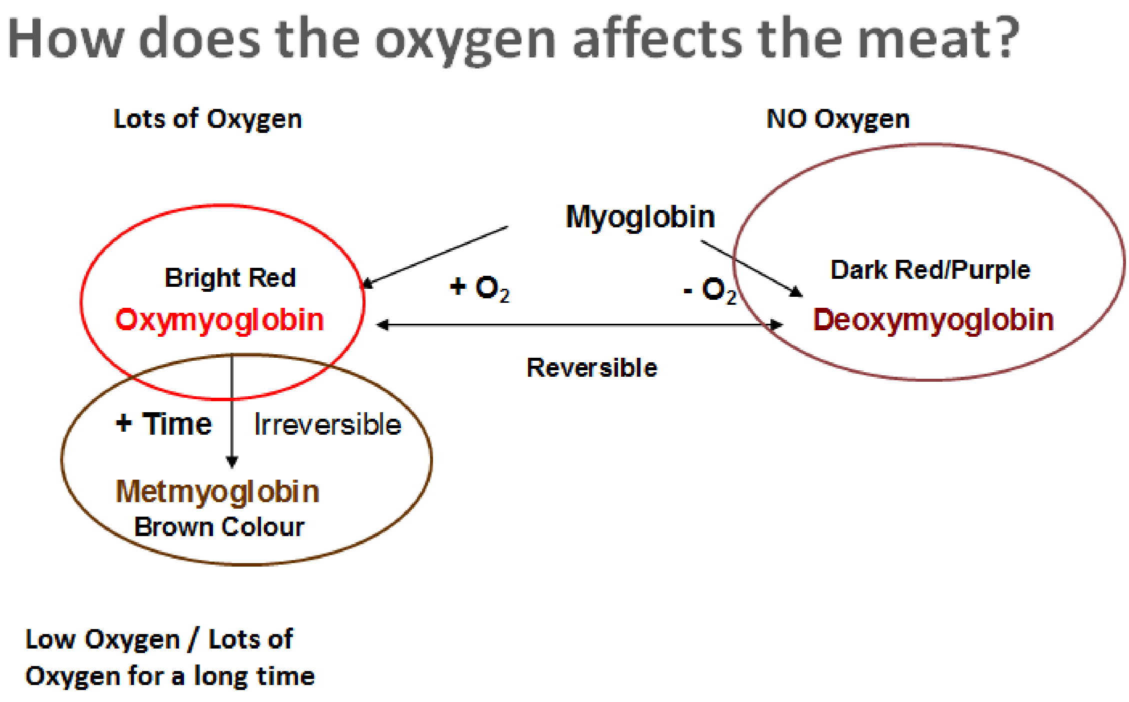

Figure 2: The effect of oxygen on meat

MAP is an effective food preservation method for meat. Using MAP increases product life and improves performance at the point of sale because it retains the fresh character of the products, maintains the attractive red colour, limits the rancidity due to oxidation and reduces the spoilage of meat and meat products. Due to its high moisture, meat and derivatives are particularly susceptible to bacterial growth. Carbon dioxide has a strong inhibitory effect on growth of putrefactive bacteria (Hudson *et al.,* 1994; Bell *et al,.* 1995; and Avery *et al.,* 1995), which represent a major problem in fresh meat. In order to obtain an attractive appearance, it is important to maintain a certain level of oxygen in the package combined with the carbon dioxide so as to maintain the red colour typical of meat. According to some studies, typical oxygen concentrations range from 70% - 80%, with carbon dioxide making up the remaining percentage or found as low as 10% - 20% and nitrogen (an inert gas, not making any significance change to the product) making up the remaining percentage (Degirmencioglu *et al.*, 2012; Church and Parsons, 1995). In Factory X minced meat is packed using a concentration of oxygen range from 75% - 83% and a carbon dioxide concentration range from 16% - 24%.

MAP is one of the preservation and packaging techniques that facilitate the increasing demand of consumers for safe, additive-free and high nutritional value food. This packaging system influences the behaviour of meat, since it alters the internal environment of the package, also known as microenvironment. The system not only reduces the contamination of meat, by acting as a physical barrier, it is an effective water vapour barrier, preventing loss through evaporation. However, the main feature of changing the atmosphere is the effect on meat colour and the reduction of microbiological deterioration during storage (Macedo *et al.,* 2009; Laury *et al.,* 2006).

MAP is an effective food preservation method for meat because it retains the fresh character of the products, maintains the attractive red colour of the product limits rancidity due to oxidation and reduces the spoilage of meat and meat products (Mancini and Hunt, 2005). The process of MAP consists of adjusting the composition of air within the pack. The atmosphere around the product is replaced at the time of packaging for another specially prepared for each food type, which allows the control of chemical, enzymic and microbial reactions, avoiding or minimizing the main degradation produced during the storage period (Macedo *et al.,* 2009).

Food starts to decompose as soon as it is harvested or slaughtered, because once plant, vegetable, fruit or animal tissue has died, there is no longer any protection against bacteria, moulds and yeasts, or from the activity of enzymes. That is why storage methods and conditions should aim to reduce the rate of decomposition to safeguard the nutritional value, appearance, taste and fitness of food; nevertheless the main purpose must be always to promote food safety (Chen *et al.*, 2012; Church *et al.*, 1995).

There are a variety of ways to preserve meat, including the use of low temperatures, use of high temperatures, dehydration, chemical methods and physical methods (Stevenson and Nash, 2007).

Using MAP to pack perishable products is achieved by introducing a gas mixture (in most cases carbon dioxide, oxygen and/or nitrogen) to inhibit proliferation of microorganisms and to retard enzymic action on certain natural products (Dansensor, 2012). The result is a product which remains fresh for a longer period without the need to freeze. Another important benefit is that MAP reduces or even eliminates the need for preservatives, a requirement increasingly demanded by the modern consumer. But the profits related with this technology include also benefits to the retailers in connection with logistics, product presentation, value added products, extended food shelf life. In Factory X minced meat is packed using a concentration of oxygen range from 75% - 83% and a carbon dioxide concentration range from 16% - 24%. All of those concentrations are as recommended by Dansensor (Dansensor, pers. comm.).

Packaging fresh meat such as beef, pork and poultry in MAP presents an interesting challenge because of competing factors. The types of bacteria that tend to cause spoilage in meat are the aerobic bacteria – they need oxygen to survive. These include the pseudomonads and other bacteria. Consequently a low-oxygen atmosphere would seem to be desirable. However, for meat products, particularly red meat such as beef, one of the main problems of storage is ensuring that the meat retains its attractive red colour: in the open air meat tends to turn brown (Mancini and Hunt, 2005). Carbon dioxide has a strong inhibitory effect on growth of putrefactive bacteria, which represent a major problem in fresh meat. In order to retain the red colour, it is important to maintain a certain level of oxygen in the package combined with the carbon dioxide (Degirmencioglu *et al.*, 2012).

Bacteria consume O_2 and produce CO_2 during growth and this has a consequence on meat pigmentation. As the oxygen is responsible for the red colour, the discolouration process may occur whether bacterial growth is noticed. MAP can favour the dominance of a facultative anaerobic population (Doulgeraki *et al.,* 2012). The evidence has been also presented in other studies; according to Hussein *et al.,* (2015) oxygen concentrations range from 70% - 80%, with carbon dioxide making up the remaining percentage or found as low as 10% - 20% with nitrogen (an inert gas, not making any significant change to the product) making up the remaining percentage. This is also corroborated by The Meat Industry Services (MIS) Section of Food Science Australia on an article published in 2001 on the newsletter Meat Technology Update.

The concept of packing fresh red meat under high concentrations of O_2 to retard metmyoglobin (browning) formation has been recognised for many decades. High concentrations of O_2 were used to increase the amount of oxymyoglobin at and beneath the surface of the meat tissue and a bright red colour. This high O_2

concentration does not inhibit the growth of aerobic spoilage organisms but this can be reduced by the addition of moderate amounts of CO_2 to the gas mixtures. When the CO_2 content of a gas mixture exceeds 20%, the rate of growth of the microbial population is approximately halved. Therefore, an atmosphere of around 80% O_2 and at least 20% CO_2 is beneficial for both microbiological quality and meat colour. In practice atmospheric mixtures of 60-80% O_2 and 20-40% CO_2 are commonly used (MIS, 2001).

As aforementioned, when exposed to O_2, fresh meat will exhibit the bright red colour characterised by oxymyoglobin formation. However, low concentrations of O_2 – around 0.5 to 1% - lead to rapid onset of irreversible browning. These conditions must be avoided by either keeping the O_2 at much higher levels or by excluding it. The role of CO_2 is primarily to inhibit the growth and metabolism of microorganisms. CO_2 selectively inhibits the growth of Gram- negative spoilage bacteria such as *Pseudomonas*, and, in doing so, may allow other bacteria, such as lactic acid bacteria, to predominate. The lactic acid bacteria cause spoilage only after extended periods. CO_2 acts as a microbial inhibitor by dissolving in the liquid or fat at the surface of the product and then producing small amounts of carbonic acid which reduces the pH (Luno *et al.,* 1998; Djenane *et al.*, 2005).

An important consideration with the use of CO_2 in MAP is that it is highly soluble in muscle and fat tissue. It will dissolve into the meat in an approximate 1:1 ratio (1 litre CO_2 per kg of meat). The solubility of CO_2 is temperature dependent and increases at lower temperatures. Headspace calculations must take the solubility of CO_2 into account when planning the packaging parameters. When using a CO_2-rich mixture in packs, the ratio of the total package volume (in litres) to the meat weight (in kilograms) is dependent on the gas mix composition and could be up to 3:1 for mixtures in which CO_2 predominate.

In practice, with packs containing high O_2 and moderate CO_2, a compromise between that ideal and a tolerable pack size means ratios are usually somewhat lower. A minimum of 20% CO_2 throughout the storage period should be aimed for as explained later. The fact that CO_2 can be either generated from meat as mentioned earlier, or absorbed into it, means that the concentration of CO_2 in packs can vary depending on such factors as its initial concentration in the mixture and the storage temperature.

MAP in high oxygen atmospheres promotes pigment oxygenation maintaining redness during storage, but also it could reduce the stability of smell and taste as it allows the growth of aerobic microorganisms. Undesirable odours and flavours can develop even before the colour gets worse. MAP with a high content of oxygen is effective in maintaining the desired red colour for periods no longer than 10 days in refrigerated storage (Degirmencioglu *et al.,* 2012).

The use of high O_2 MAP is suitable for products that are to be held for short periods of time and in which a bright red colour is most desirable throughout the display life. Temperature control is critical to the success of this application. Poor control will lead to growth of spoilage organisms and premature browning of the meat.

Minced meat is more sensitive to oxidation because of its porous structure and it has more susceptibility to microbial spoilage due to its initial load and mincing process. In other words, lipid oxidation is particularly pronounced in minced meats in which the disruption of the muscle structure exposes labile lipid components to oxygen (Degirmencioglu *et al.,* 2012). Additionally, minced meat has a greater surface area.

Safety of MAP

Concerns have been expressed that the increase in shelf-life of low-O_2 MAP meats through inhibition of spoilage bacteria may provide sufficient time for human pathogens to grow to dangerous levels while the food still remains attractive to the consumer. *Clostridium botulinum* is of most concern because of the severity of illness it causes and because of its ability to grow at high levels of CO_2 and in the absence of O_2. Some strains of *C. botulinum* are known to produce toxins at temperatures below 4°C (USDA/FSIS, 2011). Whilst there is a potential risk, problems can be avoided by ensuring that extended storage of the packs routinely occurs at or near 0°C. Pathogens those are able to multiply at chill temperatures, such as *Listeria monocytogenes* and *Yersinia enterocolitica*, are also of concern in MAP meat products (Harrison *et al.*, 2000). Both of these organisms are capable of slow growth at temperatures as low as 0°C, but are inhibited significantly by high levels of CO_2 (Harrison *et al.*, 2000; Hudson *et al.*, 1994). Above 8°C, other pathogens capable of tolerating high levels of CO_2 such as Salmonella spp. and enterohaemorrhagic *Escherichia coli* (EHEC) may pose a risk to the consumer. However, as with other chilled meats, under no circumstances should MAP product be held at more than 5ºC. Temperature abuse is the most important extrinsic factor influencing the storage life of fresh meat, whatever the packaging system. (Sun *et al.*, 2012; Mullan *et al.*, 2003; *Mossel et al*., 1992)

MAP of fresh meats is generally considered less hazardous than MAP of ready-to-eat foods because cooking (if correctly carried out) will kill all vegetative pathogens. However, microbiological contamination is a concern and MAP is not a substitute for poor hygiene and the greatest of care should be taken when producing MAP fresh meats. Any packaging technology is only effective if high standards of hygiene and temperature control are maintained.

The shelf life of the meat packaged in MAP conditions depends on gas concentrations and other factors including storage conditions, temperature, and degree of contamination of the initial carcass, the permeability of the packaging film to oxygen and carbon dioxide and the headspace volume in the package. The shelf life is often associated with low temperatures during storage (Degirmencioglu *et al.,* 2012).

By selecting appropriate levels of CO_2, it is possible not only to retard overall growth of microbial contaminants, but also to change their composition, in order to obtain a selective delay in organisms with high potential and with a rapidly grow, which means most useful for food life. Laury and Sebranek (2006) reported that high CO_2 modified atmospheres have shown a reduction in microbial growth. Although the CO_2 present has proven beneficial effects in preserving microbial spoilage of beef at concentrations of 10% to 20%, studies show that at higher concentrations (above 30%) CO_2 can accelerate the discolouration of fresh meat due to its effect pro-oxidant (Macedo *et al.,* 2009; Degirmencioglu *et al.,* 2012).

However to have success with MAP, it is essential that the companies perform all tests to assure the gas concentrations and also have the means to control whether the actual packaging process is geared to fulfil this purpose. Otherwise they may become the victim of poor experience which could damage their market position or even worse it could end the business. Dansensor explained two methods to test the gas concentrations: Random testing and on-line monitoring. The instruments used are gas analysers which measure oxygen (O_2) or oxygen/carbon dioxide (O_2/CO_2), depending on which blend is used in the packages. In Factory X the gas analyser measures oxygen and carbon dioxide.

Random Testing

In connection with modified atmosphere packaging, the basic test method is random testing, also called spot testing: Within certain time intervals - typically 20 or 30 minutes - people from the laboratory/quality assurers collect a number of sequential packages from the packaging machine. Dansensor advised that 5-10 packages is a good, representative sample. However in Factory X the teams were performing one test per line and per lane each 30 minutes. If one of the results were under or above the limits, Quality Assurers would perform a complete test per line, by other words; they would take one pack per each lane (3-4) and perform a retest. If the concentration still outside the parameters they would stop the line, call engineers and place the product in hold. If needed all products, since the last test, are reworked.

When performing tests in more than one machine, samples from the different machines must be kept separate from one another and marked with some kind of identification tag. The actual test must be performed immediately after the collection, as some products will interact with the atmosphere in the package. A gas sample from the package headspace is introduced into a gas analyser - the headspace analyser -

by way of a syringe (needle). When the needle is introduced into the package, the gas sample is automatically pumped into the analyser and the reading is instantly displayed. The needle should be introduced into the package through a septum - a kind of rubber sticker - which prevents atmospheric air from entering the package through the needle hole (Dansensor, 2012).

On-line monitoring

This technique allows a systematic in-line testing for each package which measure its on-line gas composition and calculate the targeted oxygen level. Automatic flow control enables a packaging machine operator to adjust filling speeds without impacting the oxygen level. When combined with an automated gas flushing system, the operator is able to gain greater control over both gas mix and package filling speeds. This process allows a greater control over each package assuring that each package has an optimum gas mix (Dansensor, 2012). However this technology implies extra costs to the business and the random test is a cheaper and reliable way of testing the gas concentrations ensuring they are within parameters.

Chapter 3

Methodology

1. Null hypothesis: there is no significance between meat discolouration complaints and food travel miles: Collection of all data about discolouration complaints was provided by company, thus it was necessary to locate all the claims on a map of the UK. To test the hypothesis, the distance between Factory X and each depot was calculated and the count of the number of complaints per depot was performed. The data analysis was done over a period of time (week 1 to week 14) and a correlation test was completed. The collection and statistical analysis (using Minitab 13) of data enables the determination of whether or not the null hypothesis is valid. If $P‹0.5$ the null hypothesis will be

rejected and there is a correlation between miles travelled and customer discolouration complaints.

2. Null hypothesis: Complaints are not related with stores or depots. The analysis of the data collected allow the determination of whether there is an increased number of complaints related to a particular depot or to a particular shop. If some depots or shops reveal a greater number of complaints when compared with all the others that should mean something is wrong with that particular depot or shop. Furthermore there may be a relation between the percentage of total amount of products delivered to that depot/store and the percentage of complaints related with that particular depot/store. For example it would be expected to find a higher number of complaints related with the depots for whose Factory X supplies a bigger quantity of minced meat. If that relationship is not apparent, this may suggest that the problems are related to specific depots or stores. The data is presented in a chart and analysed using statistical programmes.

3. Null hypothesis: Discolouration complaints are not related to MAP. At Factory X meat the products are processed according to a modified atmosphere packaging, using a mixture of CO_2 (minimum 16%) and O_2 (minimum 75%).It will be necessary to confirm the gas mixture composition in all products. The experiment will be carried out for periods of two days using a gas analyser – the digital PBI Dansensor checkmate 9900 - to monitor the carbon dioxide and oxygen concentration inside some finished packs, just after sealing. At least

eight tests per product should be carried out for each of those days. Gas Results for Beef minced products in two different dates

4. Null hypothesis: Shelf life is insufficient to avoid discolouration complaints. Beef minced products were used. Samples of healthy beef (500g packs), steak beef (500g and 750g packs), standard beef (500g and 700g packs) and value beef (500g and 700g packs) were collected kept refrigerated below 4ºC and sent to the accredited laboratory for testing against microbiological requirements and limits. At each time it was used six packs of each using the oldest meat (if possible) and the discolouration process is observed during a 12 day period. The surface meat colour measurements were measured according to the Tesco quality manual and photographed. Results were recorded and analysed.

5. Null hypothesis: Temperature abuse is not related with discolouration complaints. Two methods were used to test this hypothesis:

➢ Using an IR-Micro digital infrared thermometer, product temperature was tested in a few different scenarios and storage/temperature conditions:

- The minced meat temperature was tested when product is placed on refrigerated shelf. This test was performed in 6 different visits.
- Product was placed on the trolley and temperature tested after being paid for / before placed on car's boot. (Time spending shopping around vs temperature).

Product left in the car while going for shopping. Temperature checked before placing it under refrigerated conditions. The temperature tests were performed in 6 different supermarkets with 6 different products. In order to try to simulate real situations, in two of those experiments the shopping bags were left inside the car while going to do other shopping and having some lunch. Those products were placed under refrigerated conditions 2h and 4h after being tested on the supermarket for the first time. On the other four experiments all fresh products were placed on the fridge after 20 minutes leaving the supermarket. The IR-Micro digital infrared thermometer was used on the top pf the product packaging and the temperature reading noted. In all experiments this was measured while the product was in the refrigerated shelf. Temperature readings of the products were also taken at the checkout, car park and at home (depending on the specific experiment). Further details of each experiment are specified in Results and Discussion chapter. The IR-Micro digital infrared thermometer can provide fast and accurate temperature readings. The accuracy is +/- 2% or +/- 2 ºC (0 ºC to 260 ºC) otherwise +/- 4ºC within the range of -50 ºC to 260 ºC. In order to validate those ranges the probe was calibrated using boiling water and ice.

➢ It was necessary to perform a customer behaviour study to ascertain if there is any relation with complaints on:
  - Customers leaving goods in cars for long periods of time;
  - Customer buying good on the end of use by date;
  - Customers buying goods with visible discolouration;
  - Customers not aware of the myoglobin process and not allowing time with oxygen;
  - Customers shopping first fresh goods.

  A questionnaire was written (Chapter 4) and placed on SurveyMonkey and the results analysed.

Chapter 4

Results and discussion

Food Travel Miles

The main hypothesis behind the study linked the discolouration complaints to food travel miles. To prove the link a relationship between complaints and remote depots must be presented, in other words the data must evidence a higher percentage of discolouration complaints in depots located at the opposite end of the country. However from the beginning of the study it was clear that this hypothesis had a few weak points: products are not sold after the used by date; products are transported and stored under regulated guidelines which means they should not be exposed to temperatures over 3ºC. Factory X requests temperature validation exercises from the haulage companies. All transportation temperatures are recorded and monitored to ensure product is always kept under the refrigeration conditions. The analysis suggested that there is no relation between discolouration complaints and food travel miles and this can be observed on figure 3:

- Avonmouth showed a greater number of complaints (103) and it is located just 140 miles from Factory X whereas Livingston registered 64 and is 526 miles away
- Belfast is 576 miles from Factory X and showed just two complaints whereas Peterborough at 313 miles away from the factory, presented three complaints.
- The data suggested that depots and discolouration complaints are linked (P<0.001), with some depots presenting a large number of complaints.

However those results must be adjusted to take in consideration the amount of product delivered to each depot.

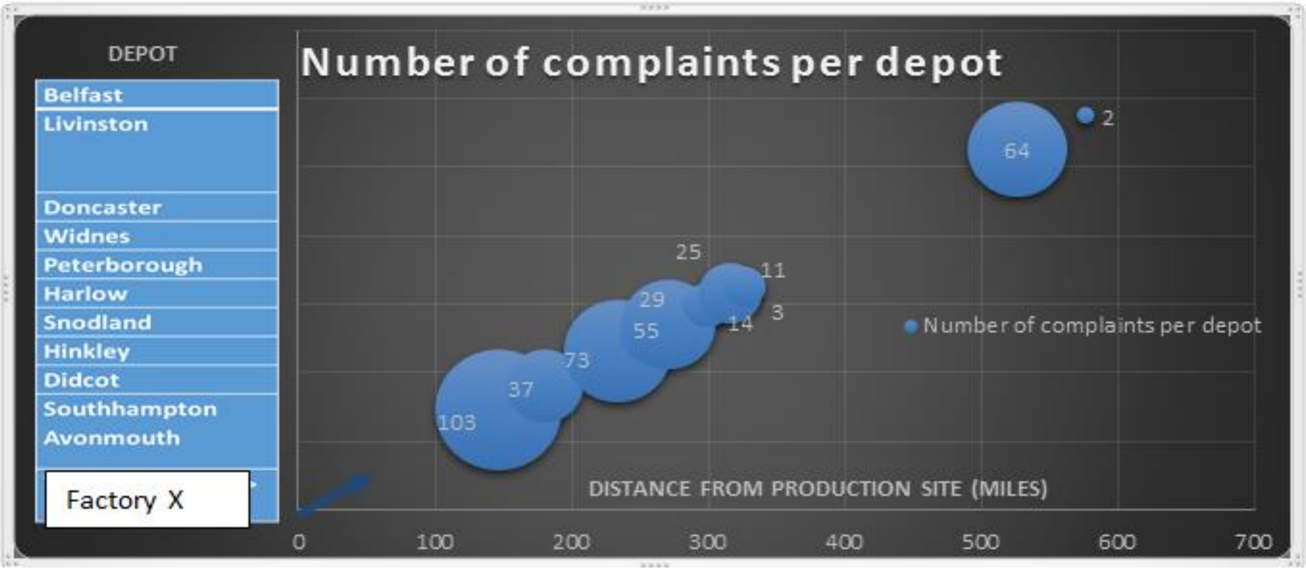

Figure 3: Number of complaints per depot in relation to distance travelled

The data suggested that depots and discolouration complaints are linked; some depots present a large amount of complaints. When volume of product was factored in, was this still the case?

Observing Figure 4 and comparing depots orders and depots complaints there appears, in some of them, to be an evident relationship between discolouration complaints and depots. It is natural that a depot which receives a greater amount of product should present a greater number of complaints, but it should be proportional. To analyse this hypothesis both percentages of discolouration complaints and depots orders were calculated so it could be compared. A correlation test was performed and the result for week 1 – week 14 found was P=0.72 and for week 15 – 35 the result found was P=0.75.

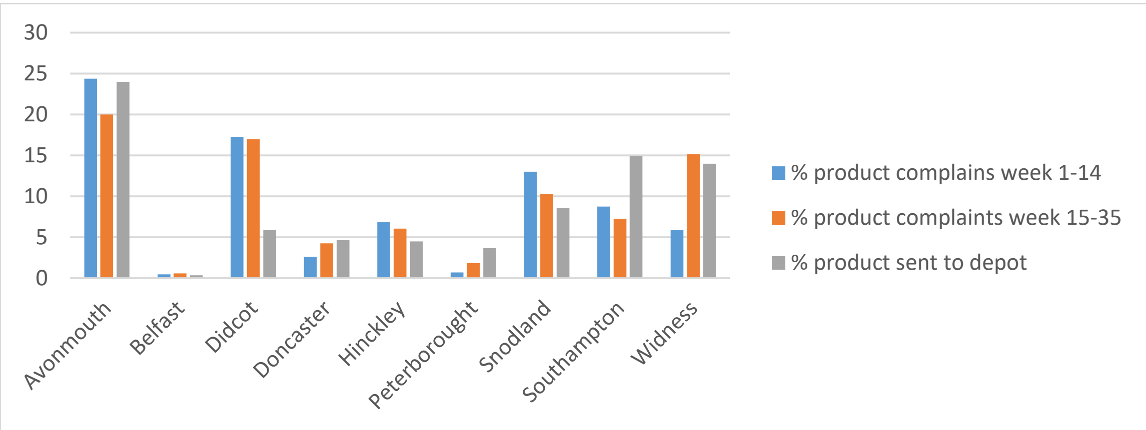

Figure 4: %Complaints vs % product dispatched to each depot

Analysing Figure 4, there are three depots where the percentage of complaints is not proportional to the amount of product dispatched to them: Didcot, Belfast and Snodland. Those depots are showing more complaints than was expected for the volume of product delivered into them. This needs to be further investigated. A full audit must be performed on those depots to assess the PRQ, HACCP, temperature control and stock rotation but also staff training and new starters on the period of time affected by complaints. Evidence and records need to be provided and analysed and if non-conformities were found a root cause analysis and corrective action have to be seen.

In 2013 (Jan. - Jul.) 125 customer complaints for discolouration were recorded for minced meat products. Avonmouth showed 26 discolouration complaints in minced products; Didcot 15 discolouration complaints; Hinckley 10 discolouration complaints; Doncaster, Livingston and Snodland verified 5 discolouration complaints each; Peterborough recorded 8 customer complaints for discolouration; Southampton showed 7 discolouration complaints. Widnes recorded 25 customer complaints for discolouration and Dagenham 19.

MAP results

In Factory X minced meat is packed using a concentration of oxygen ranging from 75% - 83% and a carbon dioxide concentration ranging from 16% - 24%. Nitrogen will complete the concentration in the packaging. The procedure for gas testing requires, depending on the duration time that the product is running, at least one check per product, 2 checks per hour. To ascertain if there was any relation with MAP and meat discolouration tests were performed during some separate dates and the results were recorded in Table 1 below.

Table 1: Gas Results for Beef minced products in two different dates

O2 day 1	CO2 day 1	O2 Day 2	CO2 day 2
76,6	16,8	75,7	16,3
75,2	17,3	79,5	16,1
74,5	16,1	76,8	18

79,5	16,5	75,1	17,1
75,6	17,8	79,2	16,9
77,3	16,9	77,4	16,6
75,1	16,3	75,4	17,1
74,3	17,4	76,1	16,5
75,9	16	75,9	17
80,3	16,6	77,3	16,1
78,1	18,3	75,3	16
80.4	17	77.1	17.2
75	16.3	80.9	16.6

As observed there were only two situations where the O_2 level was lower than 75% but more than 74%. When the result is below the minimum a retest is required straight away and if there is a problem the line will need to stop, engineers called, technical department informed and the product produced since the last expected result must be placed in hold. This confirms with the studies of Mancini and Hunt (2005) and Degirmencioglu *et al.*, (2012); the oxygen concentrations range from 70% to 80%, with carbon dioxide making up the remaining percentage or found as low as 10% - 20% and nitrogen (an inert gas, not making any significance change to the product) making up the remaining percentage (Degirmencioglu *et al.*, 2012). The carbon dioxide will stall the growth of microbes that spoil fresh meat, and so both objectives, attractive appearance and a slow rate of spoilage, can be achieved." That range is also corroborated by Dansensor (2012), especially when it concerns red meat; with the appropriate MAP mixture – typically between 60 and 80 per cent oxygen.

<u>Shelf-life results</u>

Shelf life of products is determined by considering the factors that will affect it and such a model was described by Koutsoumanis *et al*., (2006). In Factory X there is a periodical schedule list for the review of shelf life samples in order to ensure that the shelf life is appropriate. Six samples of finished packs are collected according to the scheduled list (at least two different products per month. The product collected must have been produced, preferably, with the oldest meat) and sent to the internal laboratory where it will be tested for microbial count and sensory factors such as colour/discolouration. Tests are performed to simulate different temperatures and storage conditions. Results have been analysed by the laboratory technicians over years and recorded. As it stands the use by date given to minced products is two days less than the shelf life of the product. Beef steak products in Factory X have seven days life after processing. In 2013 the laboratory performed 24 shelf life tests to those products. In 66.67% of the tests the product was acceptable on day 10. The remaining 33.33% discolouration was visible either on day 9 or day 10 but never before. For 2014 in 77.78% of the results performed to beef steak products no discolouration was visible on day 10. The 22.22% remaining tests did not evidence any discolouration on day 8. The results for 2013 are shown on Figure 5 and for 2014 in Figure 6.

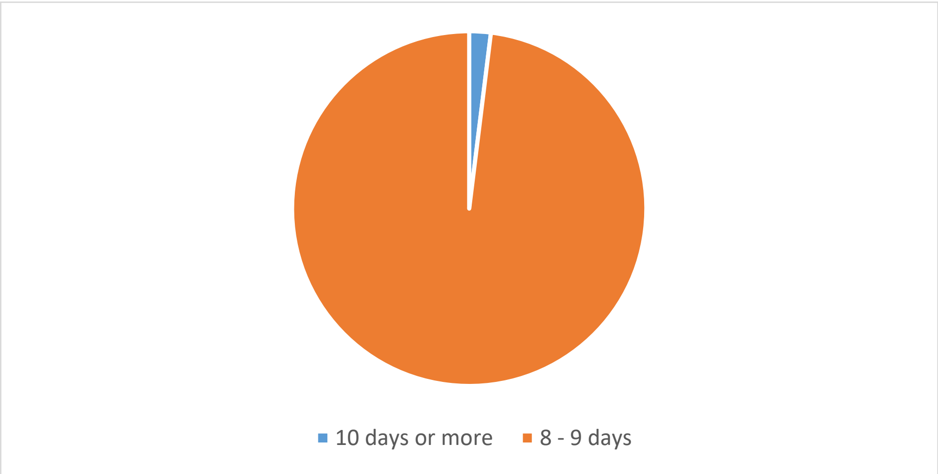

Figure 5: Shelf life results in 2013 for Beef Steak – days with no discolouration

As mentioned before the company determines the use by date taking two days from the standard shelf life of the product. Analysing the results for 2013 there was never any experiment where discolouration or bacteria were evident before day 9.

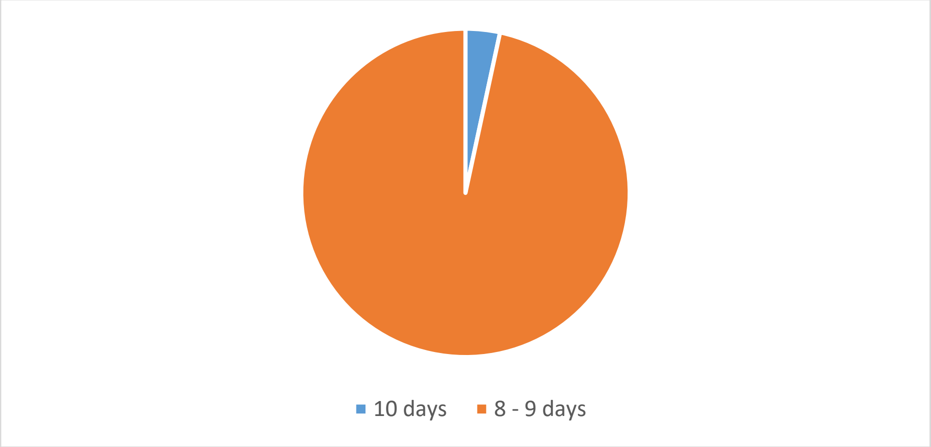

Figure 6: Shelf life results in 2014 for Beef Steak – days with no discolouration

Analysing the data for 2014 it is also evident that there was neither discolouration nor significant bacteria count on day 8, being only visible on day 9 or afterwards.

When it comes to standard and value beef products (in which fat contents are greater) the company gives eight days life to the product. For 2013 on 66.67% of the shelf life tests performed on the laboratory no discolouration was visible on day 11. Only in 4.76% of the results the product was showing discolouration on day 9. The remaining 28.57% of the results showed discolouration either on day 10 or day 11. In 2014 in 66.67% of the results showed no visible discolouration/significant bacteria count on day 11. In 33.33% of the results there was discolouration/significant bacteria count on day 9. The results can be seen in Figures 7 and 8.

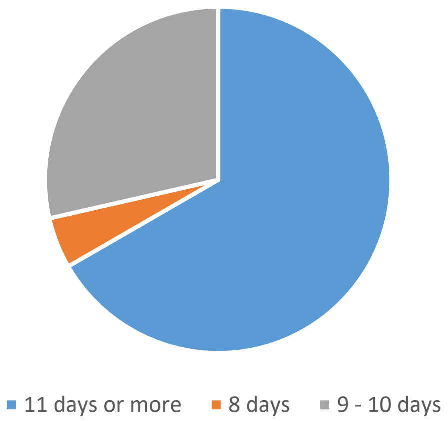

Figure 7: Shelf Life results in 2013 for Beef Standard/Value – days with no discolouration

As for steak products, the use by date of standard and value beef products are also determined taking two days from the standard results for shelf life. As can be observed in Figure 7 and numbers previously noted, 95.24% of the results show neither discolouration nor significant count of bacteria on day 9. This suggests that for 95.24% of the experiments the product was acceptable on day 9 and discolouration and significant bacteria count are only evident on day 10 or afterwards. In 4.76% of the experiments discolouration and bacteria count was displayed on day 9 (however the company only gives 8 days for use by date on those products).

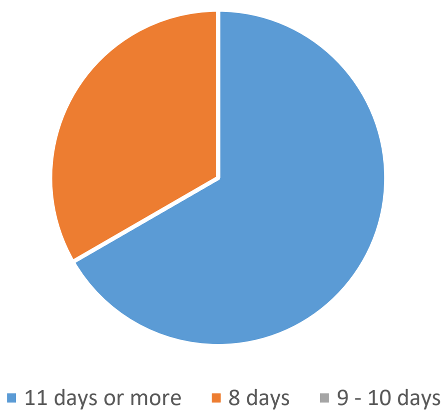

Figure 8: Shelf Life results in 2014 for Beef Standard/Value – days with no discolouration

For 2014 results in Standard/Value Beef products all the results showed that discolouration and bacteria count only starts to become significant on or after day 9. For 66.67% of the results there was no visible discolouration or bacteria count on day 11 (only on day 12). In 33.33% of the experiments discolouration and bacteria count was significant on day 9. This in particular reduces the safety margin of two days to only one day yet the product is only given eight days life.

In all cases, including steak and standard the tests showed 100% of safety on the last day given as use by date (seven days to steak and eight to standard). More experiments have been performed by the laboratory to ensure the correct shelf life of standard and value products but they were not used in this study as the outcome did not affect the product life.

<u>Temperature experiments</u>

Using the IR-Micro digital infrared thermometer the temperature of fresh meat was measured in 6 different occasions and in 6 different supermarkets. In five of those situations the temperature of fresh mince products was always over 8ºC. The lowest temperature found was 3ºC. On one occasion one of the top packs on the shelf registered temperatures over 12ºC.

After purchasing from the supermarket and before getting the product inside the car temperatures shown a variation between 4ºC and 14ºC. Tests were performed in different visits and different shops during the months of October and November 2015. They occurred on Saturdays – between 12pm and 4pm. The exception was situation six which was between 7pm and 8pm. Shops visited include superstores and express stores and product always collected from open fridges (no doors).

- Situation one:

The temperature of the product whilst still on the supermarket's shelf was 8.5ºC. The product was placed on the trolley and shopping completed before a second test was performed prior to reaching the checkout of the supermarket. At this point the temperature achieved was 10ºC. The shopping was taken home straight after and a third measurement of the temperature was executed before the sample was placed under refrigerated conditions. The thermometer showed 11.2ºC.

The product did not shown any signs of discolouration at this point. The product was then kept in a domestic fridge under 5ºC. On the use-by-date the product started to show discolouration as shown in Figure 9. The product was opened and no rotten smell was observed. The product was cooked and consumed and no organoleptic deterioration was noted.

Figure 9: Situation one

- Situation two:

The temperature of the product whilst still on supermarket's shelf was 9.9ºC. Once more, the product was placed on the trolley and shopping completed made before a second test was performed prior to reaching the checkout of the supermarket. At this moment the temperature was of 11ºC. The shopping was taken home straight after and a third test was executed before it was placed under refrigerated conditions. The thermometer showed 13ºC. The product did not shown any signs of discolouration at this point. The product kept in a domestic fridge under 5ºC. Discolouration was observed two days before the use-by-date as shown in Figure 10. However the product did not smell and was cooked without any organoleptic deterioration being noted.

Figure 10: Situation two

- Situation three:

Temperature on supermarket's shelf was 13ºC. Once more, the product was placed on the trolley and all shops were made before a second test was performed. This was before getting into the cashier. At this moment the temperature was of 14.6ºC. Shopping was taken home straight after and a third test was executed before place it under refrigerated conditions (45 minutes after leaving the supermarket). The thermometer showed 17ºC. At this point the product was no longer as fresh and appellative. Water could be seen inside the packaging and the product colour was no longer a bright red instead was getting darker. It is important to notice that only an alert consumer would realise it. If only packing the shops in the fridge without actually looking at the detail would probably miss it. The product was kept in a domestic fridge under 5ºC. It was re assed after three days and the day before the use-by-date. At this point the product was brown (Figure 11) and once opened it was found to have a noticeable smell.

Figure 11: Situation three – Temperature abuse meat showing discolouration

- Situation four:

Temperature on supermarket's shelf was 10.2ºC. Once more, the product was placed on the trolley and all shops were made before a second test was performed. This was before getting into the cashier. At this moment the temperature was of 14.3ºC. Shopping bags sat on the car boot in a sunny day while going to another supermarkets and shops. Two hours after the first test was completed the thermometer revealed 17ºC. As per situation three at this point the product was no longer as fresh and appellative. Water was seen inside the packaging and the product texture was no longer as thick but rather soft, also the colour was no longer a bright red instead was a dark red. The product was kept in a domestic fridge under 5ºC. It was re assed on the following day and the product was not fresh anymore. At this point the product was brown (Figure 12) and once opened the packaging it smelt. The product had still 4 days to its use-by-date.

Figure 12: Situation four

- Situation five:

Temperature on supermarket's shelf was 8.1ºC. Once more, the product was placed on the trolley and all shops were made before a second test was performed. This was before getting into the cashier. At this moment the temperature was of 10.8ºC. Shopping bags sat on the car boot while going to another supermarkets and shops. Four hours after the first test was completed the thermometer revealed 20ºC. Figure 13 shows how the product looked before being placed in a domestic fridge (day of purchasing). As per situation three and four there are already signs of freshness being compromised. Two days after the product was disposed of; this was two days before the use-by-date.

Figure 13: Situation five

- Situation six:

Temperature on supermarket's shelf was 3.3ºC. The product was placed on the trolley and all shops were made before a second test was performed. This was just before paying for it at the till. At this moment the temperature was of 4ºC. Twenty minutes after leaving the supermarket, at home, temperature was monitored once more. The thermometer showed 4.2ºC. On the use-by-day the product was still fresh as shown in Figure 14 and all organoleptic factors were preserved.

Figure 14: Situation six

In these six situations the products were assessed based on sensory properties rather than on microbiological analysis which could establish if the product is still safe or not. This assessment was carried out by the three sensory properties by which consumers readily judge meat quality: appearance, flavour and texture. From the three properties, colour is definitely the most important attribute at the point of purchase. If colour is unacceptable all other sensory characteristics lose their significance to consumers, because buyers they see meat discolouration as synonymous with freshness (Mancini and Hunt, 2005).

Consumers assess bright red meat as fresh and will often make choices between packs of meat on this basis alone. This means that one sense is more important than all others but that is understandable since in the supermarket the packs of meat are closed, thus the sense of smell cannot be used nor can taste or texture. As a consequence, the maintenance of a bright red colour to the meat is crucial in this industry; sales will be directly affected by the customers' interpretation of red colour as an indicator of freshness. This affects the marketability because any discoloured meat must be trimmed or sold at discount prices. Therefore, with any distribution system that involves centralised packaging, the appearance must be maintained.

From the six situations detailed above on three occasions the product was consumed and in three occasions the product was discarded. However only in one of the occasions the product properties were kept within acceptable levels at the use-by-date. Potentially it could generate five customer complaints for the other five situations. These experiments clearly show the relationship between temperature control and discolouration of the meat.

Survey

In order to try to understand if customer behaviour during shopping would show a pattern or would suggest a relation with discolouration of fresh meats, a survey was created and posted on SurveyMonkey. Social network (Facebook) was used to disclose the survey and email invitations were sent. There were two stages; the first one was released in September 2015 however an updated version (with slight differences) was unveiled in January 2016.

Both questionnaires had 10 questions with multiple choice answers. The results for the first questionnaire were downloaded in November 2015 nevertheless the last individual response was noted in October 2015. A total of 11 people filled in all responses and one extra person did not complete the full questionnaire. In January 2016 two questions were changed in order to find out if consumers know at what temperature their domestic fridges operate and how would it influence in keeping fresh products under refrigeration. After the update a new email invitation was sent and it was also promoted through social networks (Facebook). A total of 22 people responded to both stages and this is the sample analysed. All questionnaires were kept confidential. For each question a chart was generated to help with the interpretation of those results.

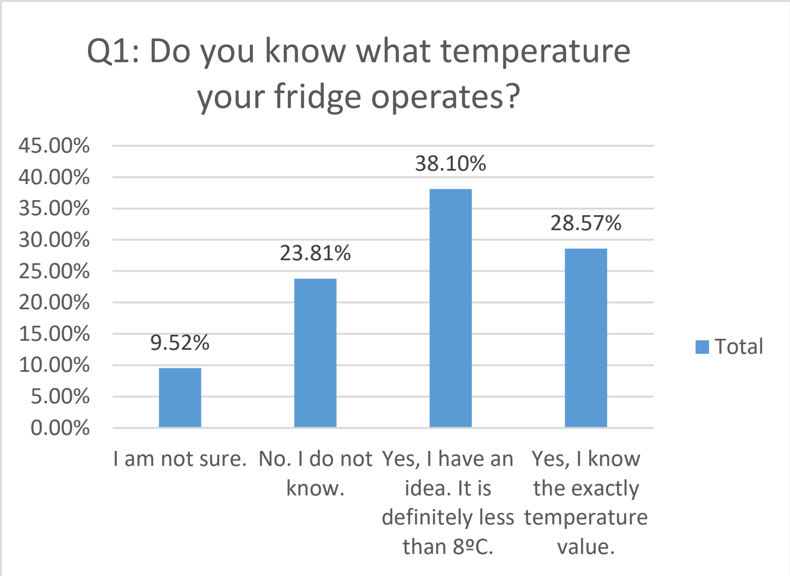

Figure 15: Question One of online Survey

As shown in Figure 15 only 28.57% of people asked knew exactly what temperature their fridges operate and over 38% knew that was less than 8 degrees Celsius. Being aware of temperature limits is crucial to keep fresh meat safe. Even within date, the freshness and quality of the meat will be compromised if not stored under the correct conditions.

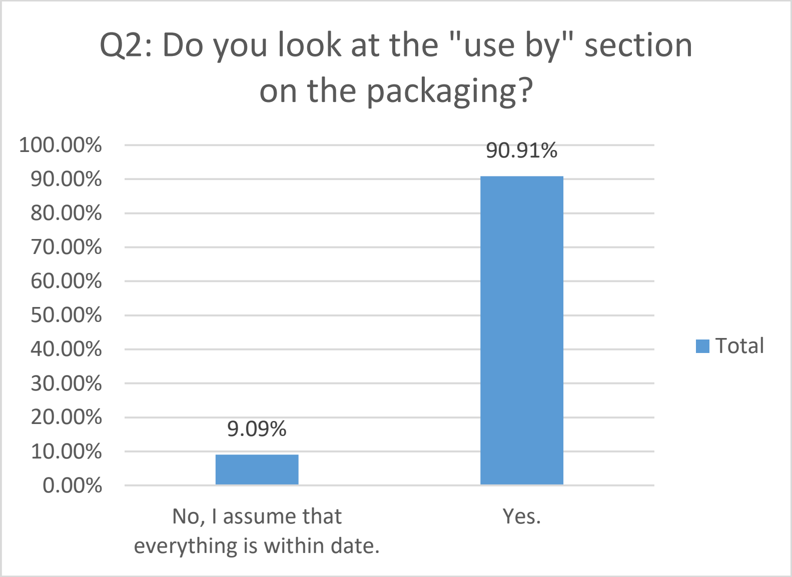

Figure 16: Question Two of online Survey

Looking at the use-by-date section on the packaging is important to ensure that the product still within date showing it is still fresh and with quality. If consumers are not aware of the use-by-date they may neglect fresh produces in their fridges and therefore observe discoloration that they were not expecting. This question was built to understand if consumers would actually look at the use-by-date section when shopping or if they would just assume products were still fresh for a reasonable time. Over 90% of people which answered the questionnaire confirm that they do look at the dates, as shown in Figure 16. On fresh products the use-by-date is synonym of safe product. The product is safe up to the use-by-date while a best before date is synonym of quality. For example dry products like cereals will have a best before date; the best before date means the product quality will be at its best if consumed before the best before date. However if consumed after the best before date, the product is still safe but the quality may be compromised. As expected the high majority of consumers will acknowledge the dates of fresh products. This question is important to assess if the meat discolouration could be associated with consumers not consuming the product within the use by date. In other words consumers were expecting to have a product fresher for a longer period just because they did not realised the use by date was shorter than what was expected. It is not the same buying a pack of meat that still have five days of life or a pack of meat which only has two more days of shelf life.

Figure 17: Question Three of online Survey

As shown in Figure 17, the questionnaire revealed that most of consumers will buy products on the last day of its use by date. On its last day products are still safe and fresh however if not consumed straight away the safety is compromised. In the specific case of minced beef discolouration can became one of the signs that the product is losing freshness and quality but also potentially that safety has been affected. Consumers cannot expect to buy a pack of fresh minced beef meat, for example, on the last day of use-by-date and leave it in the fridge for another couple days, and observe the red attractive colour. If a complaint is made under these circumstances it only means the product has been abused by the consumer.

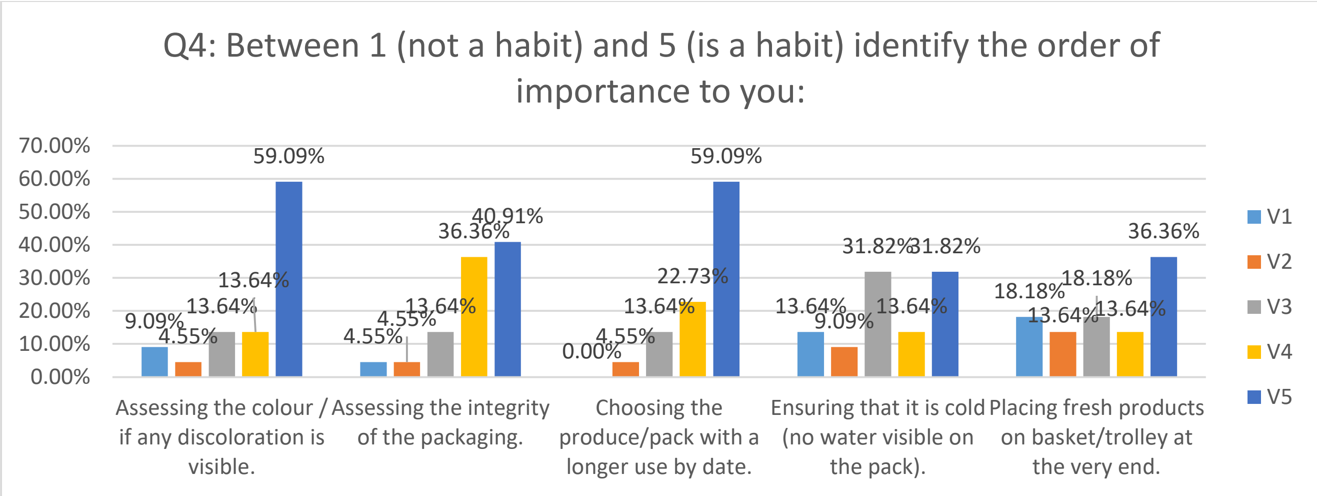

Figure 18: Question Four of online Survey (assessing from 1 to 5 - V1 represents the option not a habit, and V5 represents the option is a habit reflecting consumer's attitude/behaviour)

Analysing the answers provided on question four, Figure 18, it becomes evident that consumer will place their choices in fresh produces which look fresher and have a longer use by date. This is an expected behaviour as it shows that consumer's priorities are produces that look fresh and are safe and also it agrees with the answers provided on question two, Figure 16.

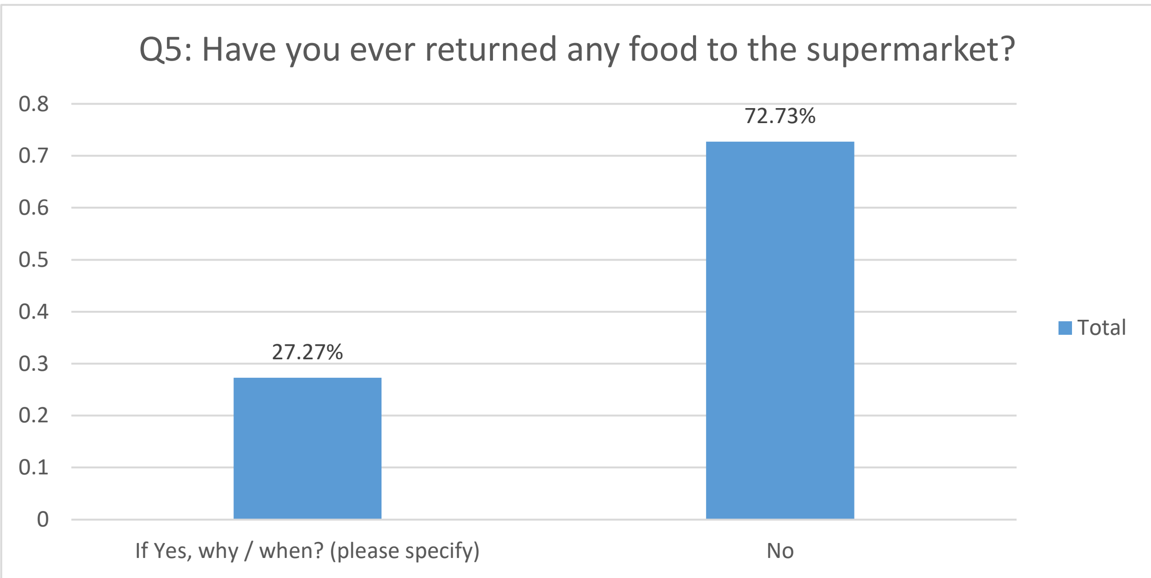

Figure 19: Question Five of online Survey

As shown in Figure 19, most people have never returned any food back into supermarkets however when they do the causes are related with sensory evaluation. This is also an expected answer following the tendency of previous answers, namely questions two and four. If consumers are paying attention to the use-by-date and consuming the product by the use-by-date and also assuming product production, storage and distribution, and final consumer's storage conditions are kept within the reasonable limits, there is no valid reason why the product should not be fresh and therefore generate a customer complaint.

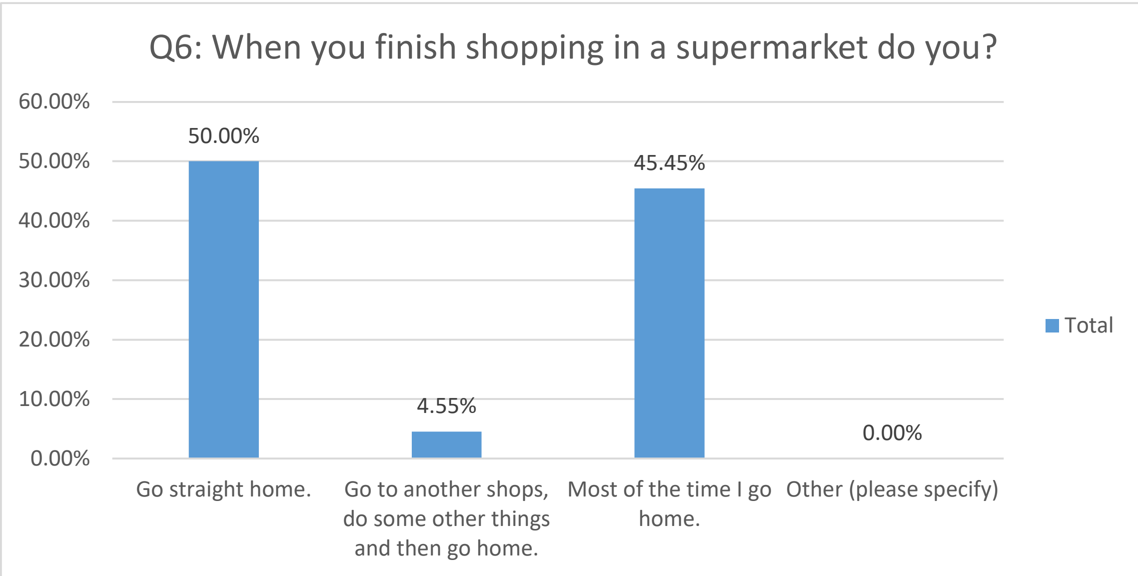

Figure 20: Question Six of online Survey

As shown in Figure 20, it is not completely to be expected that customers will go straight home after shopping. This means fresh produce may be exposed to temperature abuse for a period of time, which may compromise the product quality and product safety.

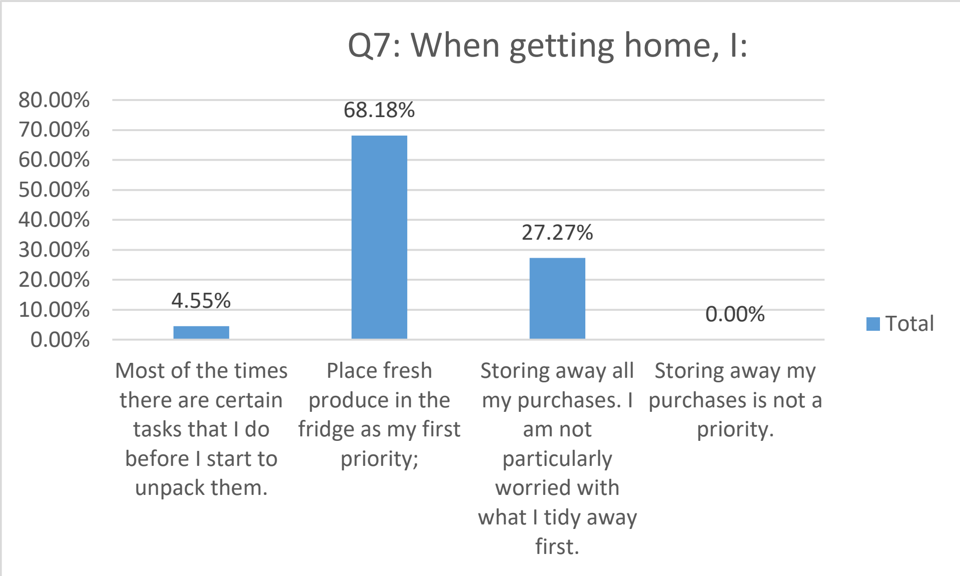

Figure 21: Question Seven of online Survey

Figure 21 show that most customers that answered the questionnaire will place fresh produce in the fridge as a first priority after shopping. This behaviour will help in maintaining food quality and safety and keeping the fresh sensory valuation.

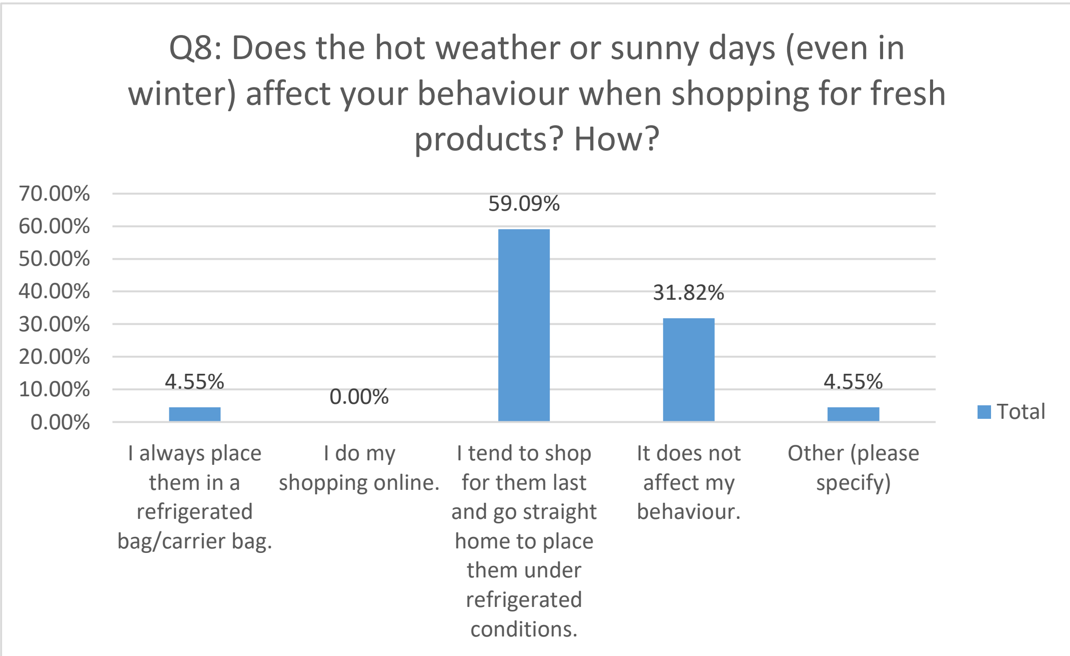

Figure 22: Question Eight of online Survey

In question eight displayed in Figure 22, most of the answers show that customer behaviour is affected on sunny days. If in Figure 20 it was not as clear that consumers would go straight home after shopping Figure 22 shows that consumers behaviour does tend to be affected by weather conditions. Responses showed that consumers are aware of the effect of hot and or sunny days in fresh products.

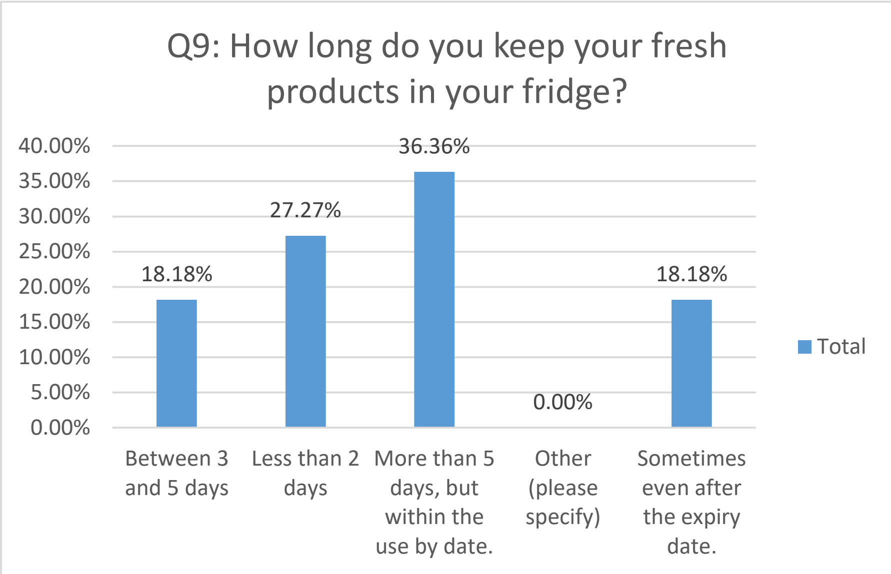

Figure 23: Question Nine of online Survey

Most customers consume products within date, as shown in Figure 23. There is however a relatively small amount of them which continue to consume the product after the expiry date. Sometimes even after the expiry date products may still be fresh and safe and organoleptic characteristics kept so this may not be a concern.

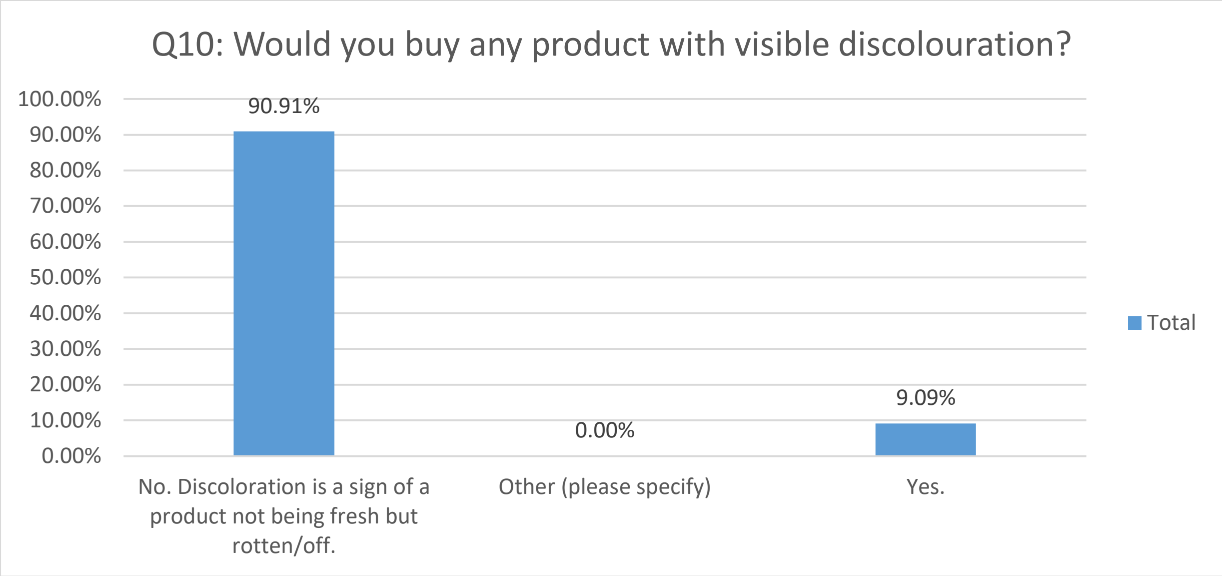

Figure 24: Question Ten of online Survey

Figure 24 clearly shows that most consumers will not buy a product presenting visible signs of discolouration. It means if the product is still retaining its bright colour consumers will buy it otherwise they will not buy it. Taking into consideration the results of the temperature experiments and the answers given, the 9% of consumers buying product with visible discoloration are probably the ones potentially complaining. Furthermore, temperature abuse can take place also after purchasing, by the consumer, and then this may result in he/she placing a complaint.

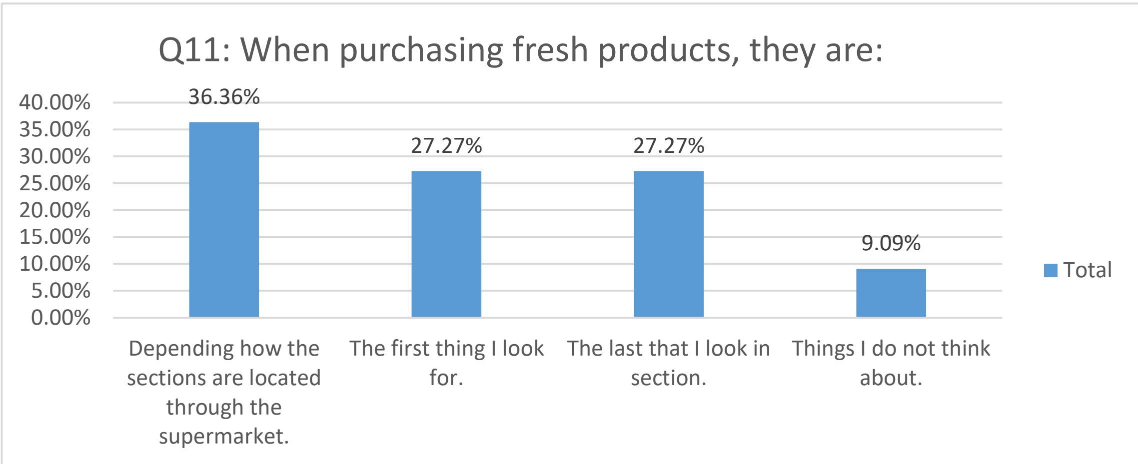

Figure 25: Question Eleven of online Survey

Supermarket layouts are designed taking into consideration marketing campaigns and consumer habits and behaviour. Each retailer will set it up in order to achieve its own goals and its own marketing strategies. Therefore consumers will be conditioned by the departments position throughout the supermarket which in many cases will affect how they pursuit their shopping list, as shown in Figure 25.

Introducing the questionnaire in this research was mainly to recognize if consumers are managing food quality well especially with regard to fresh products. It tried to determine whether or not there is a correlation between discolouration of fresh meats and temperature abuse and consumer behaviour; in other words conclude if meat discolouration is more likely to happen due to temperature abuse in the store (supermarket) or if temperature abuse is more likely to happen after purchase. However if this cannot be established only by the answers given on the questionnaire, it can be determined analysing the answers with the results of the temperature experiments. Three situations are therefore to be highlighted and discussed in the conclusions chapter:

- Consumers buying product with visible discoloration

- Temperature abuse can take place also after purchasing
- Supermarket layout can interfere on time of fresh products spending in the danger zone (between 5 °C and 63 °C).

Chapter 5

Conclusions

Many studies have been conducted on meat discolouration and modified atmosphere packaging (MAP); Mancini and Hunt, 2005; Nash, 2007; Dansensor, 2012. However the current study introduced geographical location, transportation and storage issues in relation to meat discolouration complaints. The location of Factory X in the far southwest of the UK means that products are distributed across long distances and there could be a link between discolouration and distance travelled. One of the main questions posed at the beginning of this research is whether or not the discolouration complaints are related in any way to food miles travelled. Because Factory X is located at one end of the country and all of the minced meat is destined for the retailer's depots all over the United Kingdom including Northern Ireland and Scotland, it was assumed that there could be a relationship.

This research quickly ascertained that customer complaints are not related to food travel mileage. Data analysis suggested that depots located further away were not reporting more complaints than depots located relatively close. Specifically, the meat that had travelled X miles resulted in fewer complaints than that which had travelled Y miles (eg. 564 miles 140 miles). The explanation, however, may also be related to management issues in particular depots. Some depots are showing a higher number of complaints when the volume of product supplied is taken into consideration. In this case it seems to be adequate that Factory X could trend customer complaints taking into consideration that there are some depots which are showing a weakness in this matter. It would be wise for Factory X to audit those particular depots and compare the findings with other depots. Specifically should be looking for temperature records for intakes, storage and despatch; training records for staff members including HACCP training and verifying if any new starters were introduced at the time of complaints and if training was provided; and stock rotation. Ideally Factory X should audit all the depots in order to have a more accurate data and could perform a more objective comparison. This would be the only way to approach this hypothesis.

The third conclusion drawn from this work is that with regards to MAP the data show no evidence of any break or failure in the process that could be the origin of the complaints regarding discolouration. MAP cannot be a substitute for temperature control; it does not stop the microbiological growth and cannot improve the quality (Dansensor, 2012). However it can increase the shelf-life; slow the microbiological growth; maintain the nutritional quality and slow the browning (Mullan and McDowell, 2003; Degirmencioglu *et al.*, 2012). Therefore the training, monitoring, verification and auditing procedures in place, as well the calibration techniques in place by Factory X ensure the aim of the technique.

For any company any kind of complaint made by customers requires an action to find the best way to solve the problem in the shortest time. Although there is much information and research related to beef discolouration (Mullan and McDowell, 2003;

Laury *et al.*, 2006; Degirmencioglu *et al.*, 2012; Sewald and DeVries, 2015), modified atmosphere packaging (MAP) and the best materials and packaging techniques to use, there continues to be a large number of complaints about this discolouration for Factory X mince products.

With regards to discolouration, consumers tend to consider the bright red colour of minced meat to be a sign of 'freshness' and are concerned when they find the meat is a brown-grey colour under the red surface. Minced beef has become a very popular meat choice as it is considered to be very convenient. The stressful lifestyle of modern society means that people devote less time to cooking. Moreover, the cuts in family budgets often lead to options that tend to favour quantity / price ratio. However, ground beef presents an inconvenience to the producers because of its tendency to have a shorter shelf life due to the large exposed surface area which facilitates spoilage (Mancini and Hunt, 2005; Macedo *et al.,* 2009; Degirmencioglu *et al.,* 2012) and thereby promoting shorter shelf life than other meat. Fresh minced meat can go through a number of colour changes during its shelf life. This occurs naturally, and a brown colour just under the surface does not mean that the meat is old, stale or unsafe to eat. The minced meat remains safe to eat as long as it has been correctly refrigerated and consumed by the use-by date on the package. However if a package of minced meat or other meat is a brown-grey colour on the surface and this continues all the way through, it may indeed be spoiled. Spoiled meat will have off an obvious 'sour' or 'off' smell and feel tacky to the touch.

The MAP technique allows the oxygen to maintain the bright red colour on the surface of the meat. However, beneath the surface and on the bottom of the meat, where there is less exposure to oxygen, the colour is much less red and may be brown-grey. Minced meat is more likely to change colour than other whole cuts of meat because of its larger surface area. When brown-grey coloured meat is allowed to come in contact with oxygen, it will usually ‘bloom’ to the bright red colour. This information is not common sense and people in general will assume that if the meat is showing some colour change than it is no longer safe. Most of consumers have no idea about colour changes in packed meat. It is not common knowledge and obviously it will affect people’s judgement and complaints. It may be that better labelling, to inform the customer of this, could reduce the volume of false complaints.

Another hypothesis of this study was about the use-by-date not being the appropriate or the shelf-life not being enough. Beef steak meat has seven days life and standard and value beef have eight days life. At intervals through the year, the company carries out experiments assessing the shelf life to assure, at least, that the product is still fresh, and meat colour is acceptable according to the retailer’s quality standards (micro results are also taken). That means if the meat is bright red, due to the presence of oxygen, at the end of the seventh or eighths day life, the shelf life given is enough to avoid discolouration. After analysing the shelf-life results provided by the laboratory, the use-by-dates seem to be consistent and do not seem to interfere or have a correlation with the discolouration complaints.

A further reflection which must be considered before any further conclusions are drawn is that retailers will always want to ensure customer satisfaction. This means that if a customer goes back to the retailer complaining about a product, even without taking proof of what they claim (usually they only take back the receipt to prove the product was purchase with the specific retailer), retailers will reimburse customers without questioning. In some situations the amount given back to the customer is even higher than the real cost of the product. This potentially means:

1- The consumer has the product for free;
2- The consumer has the product for free and gets some money back.

Three observations have to be made here: consumers can formally complain and get refunded without questions being raised or proof of discolouration being provided or shelf-life details; and as per questionnaire answer's there are a minor percentage of consumers buying discoloured product; and most consumers will not buy visible discoloured meat. In fact, based on the temperature abuse experiments conducted there is a correlation between temperature abuse and discolouration. In fact, the questionnaire was introduced at a later stage of this research to understand if customer behaviour during shopping would suggest a pattern or would show a correlation with discolouration of fresh meats and temperature abuse which is more likely to occur after purchasing rather than during the distribution process.

Temperature abuse would seem to start at the shelf in the supermarket. In five out of six experiments the product was always above 8ºC. For most of fresh products storage conditions will state: keep refrigerated under 5ºC - even knowing the legal limit is 8ºC. Consumers will than add temperature abuse while shopping, and until the product is placed back under refrigerated conditions.

What does it means for this project?

Analysing complaints of this nature without even looking at photos, without all the details and conditions beyond the complaint, e.g. use-by-date and date when the product shown discolouration, becomes a complex task. It raised a number of significant questions: Were basic questions answered by the customer? When did the customer purchase the product? When did he realise it was discoloured? In what conditions was it kept refrigerated? When did the customer went back to make the formal complaint? Can the customer prove it? None of those details were provided in any of the complaints made for Factory X's products. When a customer makes a complaint of this nature, it is unlikely that they will provide to the supermarket evidence (meaning the pack of meat or photographic proof to evaluate the complaint) and information regarding the context of the complaint. None of those details were transmitted to the producer (factory). Was the complaint made straight after purchasing? Was it on the same day? Was the proof of purchase actually referring to the product complained about? Was the product exposed for a long time to the temperature danger zone? There are a lot of questions that have should have been asked however they were not and now there are no answers available.

There is another factor that has to be taken into consideration: the position of the fresh meat shelves in supermarkets: one major retailer was the only customer at the company at that time. When visiting this retailer's shops fresh meat products are basically one of the first shelves the customer will find at the supermarket. Usually those products are allocated on the very first corridors (marketing and purchase effects). The location of fresh meat in supermarkets implies that customers will unconsciously allow the exposure of the fresh product to the danger zone whilst they carry out their shopping. This suggests that the supermarket layout may also have some kind of influence in discolouration complaints as the time exposed to higher temperatures increases while customer is shopping.

A range of supermarkets were visited to see whether this layout is the norm for large stores and it appeared that some supermarkets prefer this layout. However, in other supermarkets those products can usually be found at the rear of the supermarket.

Customers, when shopping, should select and buy meat and a fresh product last in order to ensure it stays cold for as long as possible. Additionally, they should choose packages that are cold, tightly wrapped and have no tears or punctures. They should also ensure the package does not contain excessive amounts of liquid (NSW, 2015). Liquid may indicate it has not been kept cold enough or has been stored for too long.

It is important to state that this study could not conclude with certainty the reason for these discoloration complaints. The reason why this could not be achieved is that there were various hindrances occurring during this investigation, as follows:

- The data was not available directly. It had to be requested through a main person that would then request it from different departments. Additionally some of the data were missing and could not be found;
- The researcher time and availability. Even whilst knowing the project was in place to help the company to deal with customer complaints and trend analysis, there was no help or time managing by the company to allocate the researcher duties at work/role or at least part of it to dedicate to the research or to have direct access to the data;
- No pictures nor enough details were available about each complaint;

- Retailer’s policy on customer satisfaction meant that there was no product to review, nor corresponding paperwork to enable analysis. The final customer has the right to go back to the retailer and be refunded if not satisfied. The customer does not have to provide proof or evidence of the nature of the complaint. The retailer will charge the manufacturer for the costs involved in these complaints;

Due to the reasons highlighted above the researcher could not come to a definite conclusion. However, the project does raise some areas of concern in this matter that can be attributed not just to the industry but also to the retailers. The retailers require the manufacturers to obey tight levels of compliance and audits whilst at the supermarkets there are no inspections that can assure the final customer with regard to food safety, quality and legal compliance.

It is recommended that in future, in order to have greater control of product safety and also for the industry and general public concern, there should be more strict standards, audits and inspections at supermarkets.

All food manufacturers are subject to numerous audits: customer audits, retailers, BRC, FSA, PGI claims, Eblex, etc. The industry needs to ensure and be able to demonstrate compliance with the relevant legislation and customer specifications. For example, in meat factories such as abattoirs and boning halls, legally the meat has to be despatched below 7ºC, however most of the retailers require the temperature to be below 4ºC. Additionally, the sites will have to comply and show evidence that they are fulfilling the requisite temperature. Also storage and distribution temperatures have to be below 3ºC. Manufacturers are constantly bombarded with customer standards that are so strict that sometimes makes them wonder if it is still the food industry or if it has become some kind of pharmaceutical or research industry where levels of care are beyond reasonable explanation. However, when it comes to the retailers themselves, there appear to be that greater self-regulation by supermarkets may result in improved temperature control in store and thus fewer stresses on these products. How is it possible to find products in supermarket shelves at temperatures above 8°C? Why is the industry so scared of the retailers and ensure all requirements are complied with and do not query the lack of audits and inspections at supermarkets? Why are the food manufacturers so complacent with the lack of monitoring systems at that end? From an FBO perspective it seems that inspections, standards or third party audits ensuring that each individual supermarket is actually complying with their own standards and with legislation are not in place to ensure compliance with 100% of the time, at least they are not as strict as an FBO needs to comply with. Food preparation has to be safe "from farm to fork" and any breach in the chain may interfere with the safety of the product. Experiments conducted during this study demonstrated that temperature abuse has a negative impact in quality and potentially in food safety. It seems that the retailers exercise some sort of oligopoly of the industry. This is, however, in the hands of the retailer as they could carry out such an auditing process themselves and they would then have data to contest customer complaints.

As an example, in Factory X during production, product temperatures are monitored closely. Product core temperatures have to be below 3°C. At despatch all products are kept under refrigeration conditions and stored less than 3°C with the air temperature usually showing readings between 1°C and 0°C, and fridges set at 0°C.

An additional consideration to this study is temperature abuse due to the time that shopping is left inside cars before being placed under refrigeration. Sometimes customers will even go to other shops and leave the products inside their vehicles, which can cause a dramatic increase in temperature, particularly if the sun is shining (even if the outside temperature is cold). These results were observed on the temperature experiment and shown a correlation with discoloration.

Difficulties encountered and recommendations for improvement

Factory X at the time this research started had no control or trending in this sort of customer complaints. This problem was mentioned to the researcher as one of the main concerns at the time about customer complaints and therefore the origin of this project. As detailed previously a number of difficulties were encountered in achieving data for the study. Ideally the researcher should have visited and audited the coldstores (checking stock rotation, temperature records, training records, etc.), should have met with someone from the complaints team at the retailer side of the business, should have been presented with enough evidence to enable a thorough study.

Customer complaints are really important to any company as they allow the companies to assess themselves and promote internal audits and investigations. This is crucial so companies can outline market strategies and become both reputable and leaders on their sectors. Identifying through customer complaints that the company is facing a real issue it is an important step. However by itself it is not enough to solve the problem. It is necessary that the company develops and spends time and resources building a team and a database which can allow them to trend the issue and take the positive results they have to offer. Saying that, in this specific case was no connection between the data and the complaints. It took too long to be able to ascertain important details such as amount of product sent to each depot in each week. For some weeks the information was not available. There were not enough details in those customer complaints apart from the date they were made, depot and store details as well as product identification.

In summary, a correlation could not be found between distance travelled and discolouration complaints, but further investigation is needed to determine whether specific cold stores are following best practise in product storage and rotation. Complaints were not a factor of poor practise by factory X either in the process of MAP or in determination of shelf life, but the factory should create a proper protocol for analysing complaints on a routine basis.

The majority of consumers will not visit supermarkets to buy products, especially fresh ones, if they suspect that its freshness is compromised. When that concerns meat, in this particular case beef meat, customers will assess the quality of the meat by considering the colour of the meat. The entire discolouration complaints treated in this investigation came after the customer has purchased the product and retailers, have a policy of reimbursing of cost on the products that are the subject of complaint. It is also important to keep in mind that the recent financial crisis may have led families to take advantage of those policies in order to save some money. However, whilst this must be taken into consideration, other more reasonable explanations must be investigated.

Chapter 6

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