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The PSE Problem. A case study of an Irish Abbatoir

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Table of Contents

List of Abbreviations

ABP's Animal By Products

ATP Adenosine Triphosphate

CICR Calcium Induced Calcium Release

DEFRA Department for Envoirnment Food and Rural Affairs

DFD Dark Firm Dry

DNA Deoxyribo Nucleic Acid

DVO Department Veterinary Office

MgAsp Magnesium Aspartate

PAP Processed Animal Proteins

PCR Polymerase Chain Reaction

PSE Pale Soft Exudative

PSS Porcine Stress Syndrome

RFLP Restriction Fragment Length Polymorphism

List of Abbreviations cont'd

RYR1 Ryanodine Receptor 1

RYR2 Ryanodine Receptor 2

RyRs Ryaodine Receptors

SR Sarcoplasmic Reticulum

TSE Transmissible Spongi Form Encephalopathy

VI Veterinary Inspector

VO Veterinary Officer

Chapter One
Introduction

Introduction

Pork is one of the world's most popular meats with over 80 million tonnes produced annually. Pork output in Ireland increased by over 90% in the period from 1988 to 2002 and has been stable since then. About 3.3 million pigs are now produced annually (2004 output) and almost 60% of production is exported, export earnings in 2004 were €228 million (Teagasc, 2004).

The main aim of the pork industry in Ireland as in many other countries throughout the world is to improve the carcass quality and size while trying to keep the production costs as low as possible. This is achieved via intensive selection of breeding pigs for muscle development and high average daily gains, while trying to achieve sufficient marbling of the meat without excessive fat deposition. One of the main consequences of this continued genetic selection is an increase in Porcine Stress Syndrome (PSS) and Pale Soft Exudative (PSE) pork. PSS is a condition in pigs in which the animal becomes very susceptible to acute stress. As a result of this acute stress the meat post slaughter can display characteristics of PSE which is of a great financial cost to both the producer and the abattoir. It is however important to state that PSE Pork does not only originate from Pigs with a genetic predisposition to it. Poor management practices of pigs without the genetic traits of PSE throughout their lives can cause them to become stressed pre-slaughter and present PSE pork post slaughter. This is however less likely to happen in this group than those animals with the genetic predisposition.

PSE and Dark Firm Dry (DFD) are the two major quality defects associated with pork in European abattoirs although DFD is far less common than PSE. PSE meat is characterized by its pale colour, soft texture, low pH and it is usually exudative and watery. DFD is associated with a slow pH drop and a high final pH in contrast to PSE. Long term stress (e.g. prolonged fasting) which depletes muscle glycogen stores is a predisposing factor. DFD meat is also more prone to bacterial spoilage. To the customer at the meat counter the visual appearance of the product is of major importance, they are less likely to buy pork that is soft, wet and pale in colour (Lee & Choi, 1999) or dark firm and dry,

as a result this subject is of great importance to the industry. PSE pork also has quite a high shrinkage due to drip loss, increased cooking losses and reduced juiciness all of which make it less appealing to the consumer.

Despite some improvements over recent decades, the incidence of PSE meat in the pork industry remains a serious economic problem for producers and the processors alike. The producer loses out as any carcasses that the abattoir determine to be Pale Soft and Exudative at the time of slaughter are deemed unfit for the human food chain, as a result the producer does not get as high a price for the animal reducing profit margins. Slaughter houses have to continually invest resources in improving animal handling and slaughtering practices to minimise the incidence of PSE. This may range from building new or improving existing lairage's and changing the floor surface in the loading bay or stunning chute in an attempt to improve the ease of which the pigs are moved and thus reduce the possibility of the pigs suffering stress which in turn leads to PSE.

Aim of Thesis

To investigate the extent of the problem of Pale Soft and Exudative pork meat in Ireland through a study of an Irish abattoir, paying particular attention to its operating procedures to determine if they have any influence on the incidence of PSE.

Chapter Two
Literature Review

Genetic Background of PSE

Genetics is one of the most important factors contributing to the prevalence of PSE pork. Pork grading systems motivate producers to breed pigs which carry the gene that leads to PSE pork as these animals usually have maximum lean and weight gain (Aalhus et al, 1991). Pigs with the gene tend to consume less feed per day yet still converting this feed to lean muscle tissue very efficiently (Stanisic et al, 2012). The gene has been given many names; stress gene, halothane or hal-gene, PSS gene and finally the Ryanodine Receptor Gene (RYR1). If an animal carries the defective gene it is usually more susceptible to PSS or Malignant Hyperthermia as it is sometimes called. Pigs suffering from PSS may be found in very poor condition on arrival after transport to the abattoir. Before death, affected pigs will have been hyper thermic, panting, sweating excessively, markedly tachycardic with possible arrhythmias, trembling, hypertonic, stiff or paretic, lame and sometimes cyanotic. Muscle atrophy may be evident, usually of large muscle groups around the back and hind limbs. The skin often becomes blotchy, erythematous and cyanotic (Nevel, 2012).

Testing of Pigs

Halothane Gas Challenge Test

Before the availability of DNA testing, pigs were accessed for PSS using the halothane gas challenge test. Upon exposure to halothane gas, pigs that displayed muscle rigidity, skin discolouration and limb tremors were diagnosed as being susceptible to PSS. Continued exposure to Halothane gas in these pigs usually proved fatal (Bates et al, 2011). The Halothane test was deemed to be very useful in the diagnosis of pigs that are homozygous for the gene; however one of the major limitations of the test is that it is unable to identify pigs that are heterozygous for gene. This is a major problem for the industry as heterozygous pigs although they do not usually exhibit any anti-mortem or post-mortem signs of the condition, they do pass the gene on to their offspring which can cause continued prevalence of the condition in future generations. Another problem associated with the Halothane test is that a proportion of pigs that do not carry the RYR1 gene can react abnormally when challenged with halothane gas (Bates et al, 2011). This abnormal reaction was usually similar to the phenotype exhibited by pigs that had the defective PSS genotype, but the condition was not fatal. This lowered further the viability of this test as

an accurate means of identifying carriers of the defective gene, and thus as a means of eradication of the condition.

DNA Testing

DNA testing was later developed to improve the accuracy of the identification of the animals carrying the defective gene. The method of DNA testing used in a study carried out to determine if the Mangalista pig breed was a prolific carrier of the PSS gene and hence was it suitable to be selectively bred for clinical and medical experiments (Stanisic et al, 2012). The research was conducted on 10 pigs of the Mangalista breed. Hairs with roots were pulled from each of the pigs and they were analysed by PCR-RFLP in the Institute for Animal Husbandry research institute of Heilongjiang Academy of Agricultural Sciences in Harbin, China. The PCR-RFLP genotyping of the swine RYR1 gene was done in 3 main steps; DNA extraction, PCR-RFLP and Electrophoresis and detection of the PCR products. In conclusion the study found that the Mangalista breed was PSS negative and thus suitable for selective breeding for the purpose of clinical and medical experiments one important advantage of DNA testing is the ability of the method to identify heterozygous carriers of the gene unlike the Halothane test. Another major positive is the fact that test is non-invasive and it does not harm the pig being tested unlike the halothane test which can be fatal.

There has been evidence to suggest that certain breeds of pig may be more susceptible to the condition than others and that there may be a difference between the sexes. A study was carried out in Korea on 695 pigs using the DNA testing method of PCR-RFLP. Among the breeds tested the Hampshire showed the highest incidence and the Berkshire showed the lowest. The hybrid (Landrace X Hampshire) showed a slightly higher incidence compared to that in Landrace or Duroe. It was also showed that regardless of the breed females showed a higher incidence of PSS than males (Lee & Choi, 1999).

Physiological Background of PSE

Porcine Stress Syndrome (PSS) is a congenital, autosomal recessive pharmacogenetics disorder which affects pigs, dogs, cats, horses and humans. It is caused by a fundamental intolerance of stress due to a defective ryanodine receptor which affects closure of calcium channels in the sarcoplasmic reticulum. This leads to a sudden, sustained rise in intracellular calcium and consequent muscle contracture and upregulation of metabolism. PSS leads to an increase in metabolism and intense production of heat, carbon dioxide and lactic acid and contraction of skeletal musculature (Zucchi et al, 2007).

In the majority of the cases (50–70%), the cause of the onset of malignant hyperthermia is due to a mutation of the ryanodine receptor (type 1). Ryanodine receptors (RyRs) form a class of intracellular calcium channels in various forms of excitable animal tissue like muscles and neurons. There are three major isoforms of the ryanodine receptor, which are found in different tissues and participate in different signalling pathways involving calcium release from intracellular organelles. The RYR2 ryanodine receptor isoform is the major cellular mediator of Calcium-Induced Calcium release (CICR) in animal cells (Zucchi et al, 2007).

The ryanodine type 1 receptor is located on the sarcoplasmic reticulum (SR), the organelle within skeletal muscle cells that stores calcium. RYR1 opens in response to increases in intracellular level mediated by L-type calcium channels, thereby resulting in a drastic increase in intracellular calcium levels and muscle contraction. RYR1 has two sites believed to be important for reacting to changing Ca2+ concentrations: the A-site and the I-site. The A-site is a high affinity Ca2+ binding site that mediates RYR1 opening. The I-site is a lower affinity site that mediates the protein's closing. Caffeine, halothane, and other triggering agents act by drastically increasing the affinity of the A-site for Ca2+. The end result of these alterations is greatly increased Ca2+ release due to a lowered activation and heightened deactivation threshold.

The process of removing this excess Ca2+ consumes large amounts of Adenosine Triphosphate (ATP), the main cellular energy carrier, and generates the excessive heat

(hyperthermia) that is the hallmark of the disease. The muscle cell is damaged by the depletion of ATP and the high temperatures. Cellular constituents can also leak into the circulation, including potassium, myoglobin, creatine, phosphate and creatine kinase (Yang et al, 2003).

The Anti-mortem and Post-mortem Symptoms of PSS in Pigs

The symptoms of PSS and the ability of all staff in the lairage, most importantly the veterinarian carrying out the anti-mortem checks to recognise them, are of the upmost importance. Pigs arriving in the lairage showing signs of stress are not only of concern to the abattoir because of the decrease in quality of the final product, but also from an animal welfare point of view. For this reason it is vital that the transporter and producers details are recorded upon arrival, in the case of any welfare issues that may arise as a consequence of the transport of the pigs, for example an unusual amount of dead pigs upon arrival because of excessive stress experienced during transport.

Signs & Symptoms of Stress exhibited by Pigs on arrival at the Abattoir

As the animals are unloaded the vet must check for pigs that are showing signs of acute stress. Some of the gross signs may include marked muscle tremors, twitching of the face and rapid respiration rate. The skin may be red and blotchy, the animals may appear disorientated and they can have an elevated body temperature. Animals that are alive but suffering acute stress may die within 10-15 minutes after unloading and very quick rigor mortis (within 5 minutes) is a classical post-mortem symptom of PSS.

There are a number of other more subtle symptoms that a vet must be wary of during the anti-mortem checks. Pigs may become lethargic and as a result they can be hard to move around the lairage or off the trailer. Pigs may start to drink excessively when they are put in the holding pens in the lairage, this may be a sign of overheating and stress although in some cases it could be a welfare issue as the pigs may not have had adequate access to water previously.

Certain animals may have an increased respiratory rate where the pig can take a number of shallow breaths with its mouth open, this is caused by overheating but it can be very difficult to spot unless it is widespread in the herd. In cases of extreme muscle damage Haemoglobinuria/myoglobinura is common. A pig with red urine is quite striking and easy to spot in a small group of animals, but when a large number of pigs are unloaded it can be hard to notice this in an individual animal and the fact that the lairage has a slatted floor where the urine immediately runs through the slats into the tank and out of sight can also make diagnosis difficult.

Management of Stressed Pigs

If a pig or group of pigs are identified as possibly suffering stress during the gross examination of the herd, the animal or group of animals should be isolated and a detailed physical examination should be performed by the veterinarian. Upon examination the pig will usually have a raised body temperature sometimes as high as 40 degrees, there will also be a marked increase in respiratory rate and the pig may be stiff/lame or unwilling to move. Muscle atrophy can sometimes be seen in large muscle groups around the back and hind limbs, and the skin can be blotchy.

If an animal is diagnosed as suffering from stress it should be removed from the main herd first and foremost, if only early signs of stress are present removal and allowing sufficient time to rest can prevent progression of the condition without any further intervention. In terms of treating a pig for severe stress the vet may spray the animal with cold water to try lower the body temperature, if rigidity and blotchiness has begun, the pig should be sedated with a fast acting agent, and given hydrocortisone and bicarbonate to alleviate the lactic acidosis, an injection of vitamin E can also be beneficial. Although treatment of the condition is possible, its effectiveness is questionable especially if the condition is advanced.

Symptoms of PSS in the Boning Hall

The symptoms of PSS later in the boning hall or even on the final inspection of the carcass are the most striking. This is where the major loss of income for both the producer and the abattoir is experienced. As mentioned previous PSS will lead to PSE pork which is unfit for human consumption. PSE is usually a rarity in the boning hall or on the final inspection because if the correct welfare and operating procedures are followed before slaughter and the anti-mortem check is carried out correctly very few pigs suffering from PSS should be slaughtered and as a result very little PSE pork should be seen. Of course animals suffering mild stress or poor operating procedure post slaughter could lead to PSE pork, but this should be a rarity.

Characteristics of PSE Meat

Pale

As the name PSE suggests there are 3 main characteristics of the condition; increased paleness of the pork, very soft nature of the pork and drip loss. Increased paleness of the pork is a major problem as this makes the final product far less appealing to the consumer and in some severe cases the pork will be deemed unfit for human consumption, which in turn causes a loss of income for both the producer and the abattoir. The increased paleness is caused by the increased degradation of actin and myosin caused by the increase in anaerobic glycolysis post slaughter which in turn causes a greater degree of light reflection.

Soft

The second characteristic increased softness of the pork causes problems while processing, cooking and indeed in the overall taste of the final product. Very soft pork is also less appealing to the consumer as this coupled with excessive drip loss can cause the pork to have an almost slimy consistency. The softness of the pork is caused when water is forced out of and accumulates between the myofibrils tearing the connective tissue.

Exudation

The final characteristic excessive drip loss or exudation of the pork is a major issue in the industry. Drip loss is encountered in nearly all pork processing plants worldwide, it is a major characteristic of PSE but it can occur in normal pork if there is poor operating practices post slaughter, for example incorrect chilling. The main issue with drip loss is that whilst the carcasses are hanging overnight in the chiller, depending on the extent of the drip loss they may weigh a number of Kg lighter in the morning. This is a major issue for an abattoir who kills a large number of pigs per week. Drip loss is also a major issue in the boning hall when the carcasses are cut into smaller retail cuts; there is excessive loss of water from between the myofibrils when the meat is cut (Godfrey, 2014).

Figure *1* The Visual Appearance of Pale Soft and Exudative (PSE) Pork

Other Possible causes of PSS in Pigs

Animals may have a genetic predisposition to PSS, but if they are managed properly in the time period from leaving the farm through to the inspection of the carcass in the abattoir, PSE pork can be, if not avoided greatly reduced.

Environment

A major factor is the environment in which the pigs are reared in or the husbandry practices that they are subjected to. Animals that are reared in confinement with a very low level of stimulus can be more susceptible to stress when they are transported to slaughter. To minimise this farmers should try to include environmental stimulation for the animals. Farmers who walked through the rearing pens every day produced calmer pigs that were easier to move and thus they experienced less stress during transportation etc. Another trend is to leave a radio playing in the rearing house to allow the pigs to become accustomed to strange noises. The type of floor on which the pigs are reared on can also have an impact. Rearing pigs on plastic or metal flooring can be problematic later in the journey as the animals may not be accustomed to being driven on the concrete flooring of the abattoir which in turn can cause increased incidence of stress.

Nutrition

Nutrition has been thought to have a minimal impact on the prevalence of PSE pork although there have been some recent observations on the subject. It was suggested that a diet that was supplemented with an extra 0.5% tryptophan 5 days prior to slaughter could reduce aggressive behaviour and reduce overall stress, thus leading to a decreased amount of PSE pork (Annon, 1991). Another nutritional factor which has been linked to meat quality is Vitamin E; dietary supplementation of vitamin E (1000mg/Kg diet) for 46 days pre slaughter significantly reduces excess release of Ca^{2+} and thus prevents PSE carcasses (Buckley et al, 1995).

A report by D'Souza et al (1998) suggested that feeding Magnesium Aspartate (MgAsp) to pigs during the final week before slaughter had a beneficial effect on the pH and colour of their pork. As a consequence of this report Lynch et al (1998) conducted a study to determine if MgAsp actually had a positive effect on reducing the incidence of PSE. The objective of this trial was to assess the benefit of feeding MgAsp for five days pre-slaughter. The diet used was based on barley, wheat and soya bean and was fed ad libitum as a dry pelleted feed from the Thursday morning (1000h-1200h) before slaughter to (2000h) Monday evening, with the pigs then fasted up to slaughter on Tuesday. The control diet had previously been fed to all pigs from 35 kg live weight, pigs were weighed

at 1000h, transported 14 km to the factory at a stocking density of 0.4 to 0.45 m2 per pig and slaughtered after a 2-3 hour lairage period, PH and colour were then measured. This experiment was similar to the trial carried out by D'Souza et al (1998) in which they found a positive effect of dietary magnesium aspartate on meat quality. However, this study was a 2x2 factorial design, where in each dietary treatment half of the pigs were minimally handled and the other half were negatively or roughly handled. All pigs in the trial carried out by Lynch et al (1998) were minimally handled. They concluded that dietary supplementation with magnesium aspartate in the finisher pig diet has little influence on meat quality of pigs, where good handling practises employed during transport did. Where handling practises may have been poor the evidence from D'Souza et al (1998) suggests that it may improve meat quality.

Feeding Pre Slaughter

A further factor affecting the metabolic rate is food consumption by the animal prior to slaughter. It is widely accepted that withdrawing feed prior to slaughter is good practice although the length of withdrawal of feed has been the source of much debate. Feeding of pigs too close to slaughter has a number of undesirable effects; an increased death rate during transport, a greater risk of contamination of the carcass by perforation of the intestines during evisceration and an increased incidence of pale, soft and exudative (PSE) meat which is downgraded at sale. In addition, undigested feed is wasted and the quantity of effluent to be disposed of by the factory is increased. It was found that withdrawal of feed from pigs before the pigs were loaded for transport reduced the incidence of PSE pork and increased the final pH of meat. There was less PSE meat after a fasting period of 24hr before transportation and the ultimate pH in the loin and ham was higher than in the non-fasted group (Lee & Choi, 1999).

An interval from last feed to slaughter of 12 to 18 hours, during which water should be available is usually recommended. In France pigs with excessive amounts of stomach contents at slaughter are subject to a price penalty. Too long a fasting interval results in carcass shrinkage pre-slaughter (Lynch et al, 1998). The present recommendation in Denmark and in the Netherlands is to give pigs their last feed in the afternoon or evening before collection the following morning (Neilson, 1982, Eikelenboom, 1988).

Pre-slaughter Handling & Transportation

The next and most important factor is the pre-slaughter handling and transportation of the pigs. The stress placed on an animal prior to slaughter directly influences meat quality. High temperature or sudden fluctuations in environmental temperature is a major cause of stress in pigs pre-slaughter. When temperatures become higher than that which the pigs are accustomed to, the pigs' body temperature rises because it is unable to dissipate the heat rapidly enough; high body temperature will speed up respiratory rate and metabolic reactions, thus increasing the incidence of PSE.

Moving

The process of moving the pigs from the fattening pens to the transport vehicle and then into the lairage can also prove a source of stress. The structural design of the fattening pens, doors, races and collecting pens in the lairage are all important in facilitating the stress free movement of pigs. Pigs also move more readily from dark to light, so a well-lit floor and trailer can prove useful in moving the animals. Loading facilities on farms are very often poor; the maximum recommended angle for a permanent pig ramp is 20 degrees and closer to 15 degrees is recommended if space allows. The surface of the ramp is also very important as animals find stair stepped ramps easier to climb, so this is the recommended surface. Mixing animals of different ages and sizes during collection, transport and in the lairage can also cause a greater incidence of stress as it often leads to fighting (Defra, 2011).

Transportation

The transportation itself is also very important, the length of the transportation to the slaughterhouse and the loading density of the vehicles are relevant. A number of studies show that slaughtering animals immediately after a short journey (<1hour) leads to more carcasses showing PSE than after a longer time of transport (Faucitana, 2008). The theory behind this is that the animals on the longer journeys may experience a calming phase, which may normalise metabolic disturbances caused by loading, although this is only a suggestion

According to Department for Environment Food and Rural Affairs (DEFRA) regulations in the UK there must as a minimum be sufficient space for all pigs to be able to lie down or stand up in their natural position. The Regulation states that, in order to comply, for pigs of about 100kg the loading density should not exceed 235 kg/m2, but that more space may be needed to take account of actual circumstances. Ensuring adequate space and environmental conditions during transport will certainly enhance meat quality post slaughter (Defra, 2011).

Lairage

The optimum length of the rest time that the pigs have in the lairage before slaughter is also widely debated. A study described by (Santos et al, 1997) investigated the influence of lairage, environmental conditions, and resting time on pig carcasses and meat quality. The experimental material consisted of 1001 cross Pietrain-Duroc-Hampshire × Belgium-LR-LW pigs, held in lairage for either ≈30 min (direct slaughter) or between 2–3 h under 12 °C/90% relative humidity (RH), 20 °C/80% or 90% RH and 35 °C/50% or 85% RH. The transportation time was around 45–60 min and they were subjected to a fasting period of 36 hours before loading. Unloading operation and the driving of pigs to the point of stunning were carried out according to the practices used in the plant (sticks and electrical goads were used). Batches of 20–30 mixed pigs were used in each trial, held at a stocking density of approximately 0.55 m^2/pig (≈100 Kg live weight). The increase of lairage temperature decreased the frequency of normal carcasses, followed by a higher incidence of PSE status. The influence of lairage relative humidity on the PSE/DFD muscle incidence depended on the associated temperature, but the most significant detrimental effects were noticed in experiments carried out at 35 °C. In respect to lairage resting time, pigs kept at 35 °C/85% RH, and immediately slaughtered (they were kept for under 30 minutes in pens) generally produced less carcasses of normal quality than resting periods up to 2–3 hours (Santos et al, 1997).

The lairage itself should be well ventilated clean and have a non-slip floor. There should be plenty of space for the animals to move around in, the walls should be high enough to prevent the pigs from seeing over them, thus avoiding the possibility of being frightened by workers or vehicles etc. The lairage should be a quiet as possible to avoid causing unnecessary stress to the animals. The moving of the pigs to the stunning point also has great importance, as the pork quality can be ruined even in the last few minutes before

slaughtering. Rough handling at the plant should be avoided at all times as it may cause excess distress for the animals which will cause the pigs to overheat and this in turn will decrease the quality of the pork. Handlers need to be trained to move pig's quietly in small groups and the use of electric prods should be limited.

Stunning

It is essential that the stunning of the pigs is carried out as quickly and as humanely as possible to avoid causing unnecessary distress to the animal and thus the quality of the pork. There are 3 main techniques used worldwide in the stunning of pigs; Electrical stunning, captive bolt and the use of carbon dioxide. Each method has its pros and cons as discussed below.

Captive-Bolt Stunner

The captive-bolt stunner was one of the first pieces of stunning equipment to be developed, becoming commercially available in the UK in 1922. Today, having undergone modification and improvement, it remains one of the most versatile pieces of stunning equipment, both within abattoirs and out in the field. Although the captive-bolt is used mainly for stunning cattle, sheep and goats, it is also employed to a lesser extent for pigs, horses and farmed deer. The humane killing of livestock with captive-bolt equipment is a two-stage process. Firstly, the animal must be effectively stunned, secondly, the major blood vessels in the neck or thorax are cut; the animal dies at this point from a lack of oxygen to the brain, caused by loss of blood, or by destruction of the brainstem. The animal must remain unconscious from the initial stun until death occurs. Whilst it may appear that captive-bolt stunning is a straightforward procedure, great care must be taken in its operation, as both operator error and equipment failure will severely compromise animal welfare.

Pigs are the most difficult animals to stun with captive-bolt equipment, therefore it is seldom used. The target area is very small and this problem can be exacerbated by the 'dish-face' characteristic found in certain breeds and in aged pigs. Additionally in comparison to other species, the brain lies deep in the head with a mass of sinuses lying between the frontal bone and the brain cavity. Captive-bolt stunners can be used on most pigs, but it is recommended that the heaviest cartridge available for the equipment is used,

and that in all cases the animal is bled immediately to ensure rapid death. The site for stunning pigs with a captive-bolt is 20mm above eye-level, on the mid-line of the forehead, aiming towards the tail. Older sows and boars may also have a ridge of bone running down the centre of the forehead. This may prevent the bolt penetrating the brain cavity and the pig will not be stunned effectively. Due to the problems which might arise with adult pigs it is recommended that, where possible, they are stunned electrically, or destroyed by use of a free-bullet humane killer or a shotgun (Humane Slaughter Association, 2013).

Carbon Dioxide Stunning

Increasingly, in larger abattoirs in the UK and elsewhere, carbon dioxide is being used for the stunning and killing of pigs. For large operations with a high volume of animals passing through (e.g. 800 per hour), this is often the most reliable slaughter method for ensuring consistency in terms of good welfare and quality. For the system to be as humane as possible, it is essential that animals are exposed to the maximum concentration of carbon dioxide as soon as possible and that the dwell time is sufficient to ensure that animals do not regain consciousness before death. All operators shackling and bleeding the pigs should be capable of checking for, and recognising, signs of both effective and ineffective stunning. They must know the correct operating procedure if signs of recovery are seen.

In the case of gas killing using carbon dioxide, pigs are seen to exhibit strong reactions for a period of up to 30 seconds. However, recent research by Humane Slaughter Association has shown that some of this is reflex movement after the animal has lost consciousness and is therefore not a welfare concern. As with many gas killing systems, carbon dioxide partly acts by displacing oxygen so the brain cannot function and brain death ensues. Carbon dioxide also has a direct anaesthetic effect which results in loss of consciousness quicker than with some other low oxygen gas mixtures such as argon and nitrogen mixtures. (Humane Slaughter Association, 2007).

Carbon dioxide is detrimental to animals and exposure to high concentrations compromises welfare. However, this system has many welfare benefits including: reduced risk of

potential human error compared with, for example, electrical stunning in which there is a risk of incorrect placement of electrodes; animals remain in groups; consistency and effectiveness at high throughputs. Whilst an alternative non-aversive gas mixture would be preferable, no such alternatives are currently commercially available.

Electrical Stunning

Electrical stunning was initially developed in France and Germany in the late 1920s, for use on cattle, sheep, pigs, calves and horses. This method involves stunning the animals with electricity; death is caused either by bleeding (cutting the major blood vessels between the heart and brain), or by electrocution (by applying an electric current to stop the heart). Even in the early stages of development, experiments were carried out to determine the optimum electrical current needed to stun animals for sufficient time to enable them to be bled without recovering consciousness. In the early 1930s, high-throughput electrical stunning systems were developed in the United States of America. Electrical stunning became more widely established in Europe in the 1950s and is now used around the world.

The principle of electric stunning is to pass sufficient current through the brain to interrupt its normal activity, so that the animal becomes immediately unconscious and unable to feel pain. When electrodes are applied to the head, the amount of current that flows will depend on the voltage difference between the electrodes, and the electrical resistance of the animal.

There are two main methods in which the electrodes can be placed on the animal; Head-to-back stun-killing is carried out by passing a current simultaneously through the brain and through the heart of the animal. In order to achieve this, head-to-back systems have the electrodes fixed in a hand piece, which is applied and operated manually by the slaughter man. To ensure correct positioning of the electrodes and to maintain contact, it must only be carried out on animals held in a restrained (Humane Slaughter Association, 2013).

Figure *2* Head to Back Stunner

The correct positioning of both electrodes is very important in order to ensure that the current flows through both the brain and the heart. With the animal restrained, the rear electrode should be placed firmly in the middle of the back above the heart. The front electrode should then be placed on the head, level with, or forward of the eyes. If a switch is fitted to the handset it should only be pressed once the electrodes are in position. The rear electrode should not be placed too far back, as the front electrode will also be in the wrong place and the animal will not be properly stunned. Electrode handsets that combine a water spray will help to reduce contact resistance and will, therefore, improve current flow.

Head-only stunning can be carried out on individual animals within a group in a pen, or on individual animals in a restraint. There are two basic types of head-only tongs: scissor or fork. The site of application is the same in both cases but the method of restraint may be different. The most widely used are scissor tongs, the arms are usually around 75cm long and have a maximum jaw gap of about 30cm; the handles may incorporate a switch. The design of the electrodes varies, but is generally either a parallel array of metal teeth, or a circular cup electrode with one or more central spikes. The electrodes are connected to insulated blocks at the ends of the tongs.

Figure *3* Head Only Stunning

To enable accurate placement and maintain contact, the fork tong should only be used when stunning animals held in a restraint. The electrodes are usually longer than those found on scissor tongs, to allow for variation in the size of animals, and are connected to a single handle by insulated arms. Control equipment must be adequately protected from both physical and water damage. The easiest way to achieve this is to site the control box away from the stunning and sticking area. Provided the cable between the stunning tongs and the stunner control box is of sufficient diameter, there should be no appreciable drop in current level due to increased resistance caused by cable length. The operator must be able to see the meters which display the current and voltage, and be able to hear and see the audible and visible signals to warn if the stun duration falls below the required level. It is important that the operator has unrestricted access to the safety stop controls. Head-only stunning electrodes should be placed so that they span the brain as directly as possible. Positioning the electrodes anywhere else means that more of the current may flow through lower resistance pathways and not entirely through the brain, thus reducing the effectiveness of the stun.

When using scissor-type tongs on sheep and pigs, the recommended tong position is on either side of the head between the eye and ear. In practice, this position can be difficult to achieve on pigs because of the shape of the head; so an alternative is just below the ears, or diagonally below one ear to above the opposite eye. When using a fork-type tong the position is the same, between the eye and ear on each side of the head. In both systems,

once the electrodes are applied they must be kept in constant contact with the animal to prevent interruption to the stunning current flow, as this can lead to an ineffective stun and can also increase the occurrence of carcase damage.

Electrical stunning is often blamed for meat quality issues leading to carcase downgrading. As a result, adjustments are sometimes made to electrical equipment that could compromise animal welfare. Most conventional stunners operate with the same 50Hz sine wave as the mains supply. However, research has demonstrated that direct muscle stimulation is responsible for downgrading conditions. Increasing the frequency of the applied waveform to 1500Hz significantly reduces the level of direct muscle stimulation and manufacturers have now produced equipment which applies high frequency current followed by low frequency current. Research has also shown that, although electrical stimulation of muscles at stunning can lead to blood splash, bruising and broken bones, and the occurrence of these conditions also depends on other factors, including: the source, breed and strain of the animal; nutrition; changes in temperature prior to slaughter; pre-slaughter handling; and interrupted contact of stunning electrodes. These may account for the frequency and random nature of the incidence of downgrading between individual animals. All these factors must be thoroughly investigated before making changes to the settings of a stunner.

Bleeding

Bleeding to prevent the risk of recovery, animals must be bled as soon as possible after stunning, ideally whilst still in the tonic (rigid) phase. Bleeding involves severing the carotid arteries and jugular veins, or the blood vessels from which they arise. The animal then dies from loss of blood. It is important that all major blood vessels are severed. If only one carotid artery is cut the animal may take over a minute to die. Correct stunning and bleeding is essential for ensuring both animal welfare and meat quality. Correctly trained staff in the abattoir is a must.

Post Slaughter Issues

There are also a number of problems that may occur post slaughter which can affect carcass quality. The main issue post slaughter is the carcass temperature; the carcass temperature should be reduced as soon as possible post slaughter as an increased carcass temperature leads to an increase in anaerobic glycolysis which in turn can lead to PSE pork.

Scalding & Hair Removal

The process of scalding and hair removal of the carcass post slaughter is a common practice. Scalding will inevitably increase the temperature of the carcass and as mentioned previous this will increase the anaerobic glycolysis, the resultant low ultimate pH and protein denaturation produces the characteristic PSE condition. There has been a suggestion that skinning the carcass instead of scalding and hair removal was a better option (Troeger & Woltersdorf 1987). Skinning the carcass was a better option for a number of reasons ; skinned carcasses has improved muscle colour and water holding capacity and furthermore skinning reduces the processing time , thus the carcasses can be moved to the chiller faster which will reduce the carcass temperature faster and improve pork quality.

Chilling

Post slaughter chilling is the next point and it is of the upmost importance. A study detailed in a paper written by (Lee & Choi, 1999) the subject of post slaughter carcass chilling was discussed in detail. It was observed that chilling carcasses at a temperature of 0-2 degrees centigrade resulted in less PSE pork than those carcasses chilled at a higher temperature. In conclusion the article suggested that carcasses should be chilled rapidly after slaughter at a low temperature. Kauffmann et al (1992) suggested that there was a further decrease in PSE in plants that used sub-zero temperatures to chill carcasses although. However increased toughness has been associated with ultra-rapid chilling systems. Consequently rapid chilling at -20 degrees centigrade for 2-3 hours followed by conventional chilling was recommended to reduce the condition of PSE without affecting the tenderness.

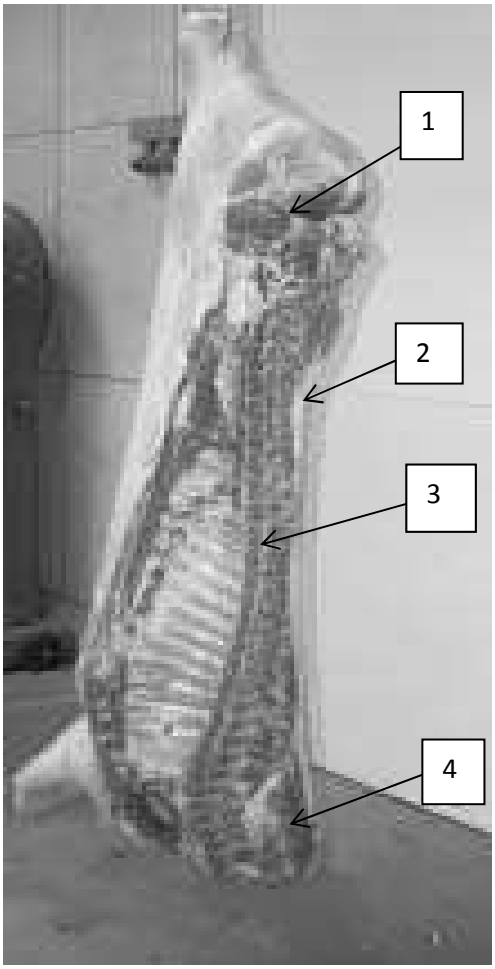
Methods of detecting PSE

The PSE condition is characterised by a rapid drop in meat pH after slaughter and a low final pH, resulting in meat which is pale in colour, has a soft texture and is exudative or watery, all of which decrease the retail value of final product and thus have a negative economic impact on the abattoir. Pork plants must be able to assess the quality status of pork accurately, quickly and economically for sorting prior to processing or merchandising. The ability of a single, on-line measurement to predict the quality status of an entire muscle or even of a whole carcass is very important. Ideally, early post-mortem on-line objective measurements are needed to predict the quality attributes of the end product.

PH reading points on a Carcass

There are many points on a carcass at which industry personnel can take readings with hand-held probes for pH, conductivity and colour. Predicting meat quality from a single on-line measurement has great commercial potential if measurement at one site can predict the status of the whole muscle or even of the entire carcass. To identify the optimum site(s) for measurements, the following factors must be taken into consideration. The sample site needs to be easily accessible. Information is required on the relationship between readings taken on the major muscles, for example the topside muscle and the striploin.

Figure *4* Sampling Sites on a Pig Carcass



Locations on a pork carcass at which pH,
conductivity and colour measurements may be recorded.

1 = topside (M. semimembranosus)

2 = oyster muscle (M. gluteus medius)

3 = loin (M. longissimus dorsi)

4 = the neck (M. biventer cervicis & M. splenius)

Technologies for Detecting PSE in Pork Mullen et al (2003)

pH Measurement

The value of the pH measurement is of the upmost importance in determining carcass quality the muscle pH of living pigs is around 7.0 to 7.2. After slaughter the lack of oxygen and nutrients reaching muscles causes anaerobic glycolysis which in turn produces lactic acid. This excess production of lactic acid induces a pH drop to about 5.5. The normal procedure for taking pH measurements is one measurement at 45 minutes post slaughter (pH1or pH45) and another at 24hr post slaughter (pH24). The two main muscle conditions associated with abnormal pH fall are PSE and DFD as previously mentioned. PSE meat can be identified by a rapid initial pH fall (lower pH45) and slightly lower pH24. Pork with a pH45 lower than 6 are very likely to present PSE characteristics.

The main reason for DFD pork is chronic stress which lasts for anything from 30 minutes to a few hours before slaughter. Prolonged food deprivation periods, transport fatigue and fighting between unfamiliar pigs are frequent causes of chronic stress. Pork with a pH24 above 6 is very likely to present DFD characteristics. There are 2 methods which can be used to evaluate the pH; the homogenisation technique or using a pH meter.

Homogenisation Technique

The homogenisation technique was described by Chizzolini et al (1993) in their study to evaluate different techniques used to test pork quality. The homogenisation technique uses 50-100g of meat obtained by trimming the uncovered surface of a predetermined sample site (in this case they used the semimembranosus).The sample is then homogenised in a solution of 0.01M iodoacetic acid and 0.15M KCL buffered at pH 7.0. The pH was then read.

pH Meters

Measuring pH using specifically designed pH meters is a faster more efficient way to measure the pH. Various companies sell these pH meters, but they all work the same. The process involves pushing the electrode from the pH meter into the chosen sample area and reading the value of the display.

Each method has certain “pros and cons”. Chizzolini et al (1993) observed that the average pH value was higher in the homogenisation technique that for the same measurement taken

at the same time using the pH meter. It was thought that this was due to the iodoacetic acid solution used in the processing of the sample. This anomaly was mainly found in the ph45 measurement and the increase was found to have disappeared as the carcass reached its final pH value.

Measurement Techniques

It is important that each measurement is taken at the set time i.e. 45 minutes and 24hr and the measurements must be taken at the same location to avoid variations in the values caused due to different muscles being measured. The electrodes of the pH meter have to be pushed into the muscle being measured sometimes up to 3cm. This means that repeat measurements in the same sample site are rarely carried out as the person carrying out the measurements wants to avoid unnecessary meat spoilage as a result of the measurement being taken and thus the accuracy achieved by repeat measurements is lost. One major advantage of the pH meter is the ability of the method to be used on a production line quickly and accurately, because of how easy and quick it is to take a measurement each individual carcass can be examined. In comparison the homogenisation technique is a longer process takes and thus it is likely that only a representative sample of the carcasses will be tested instead of each individual carcass.

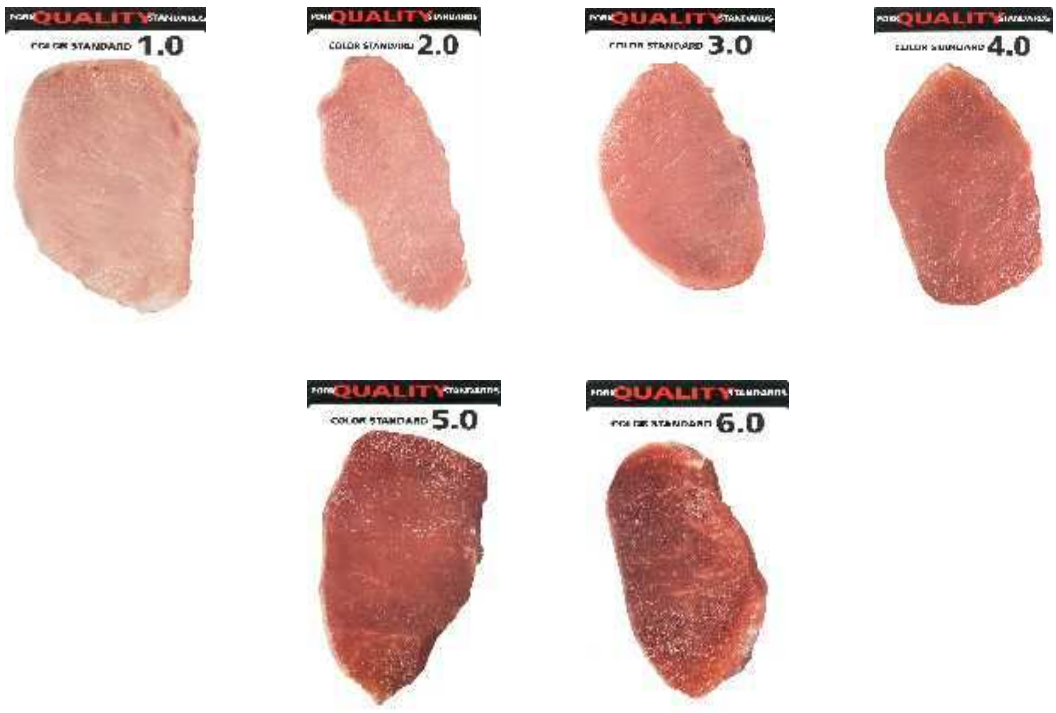
Figure *5* Measuring pH of Pork

Measuring pH of pork topside muscle using an Orion pH meter (Model 250 A) with glass electrode (Amagruss Electrodes Ltd.)

Colour of Meat

The colour is another characteristic of the pork that can be evaluated to determine if the meat is classified as PSE or not. The main difference in evaluation the colour and the other diagnostic methods, is that it is subjective. The fact that it is subjective leaves room for human error and the result may differ depending on the person carrying out the assessment, to try and minimise the possibility of human error many factories have two people assessing the colour each time. The main concept of colour scoring is that the person carrying out the assessment will have a reference colour scale, and they compare the meat they are testing to this scale and then a result is determined. There are a number of colour scales used; a popular colour scale is the Japanese colour comparison blocks produced by the Japanese Meat Organisation, Tokyo Japan. The Japanese colour comparison blocks consists of six blocks of a meat like polymeric substance Block one is a pale colour and it represents extreme PSE meat, while block 6 is a dark colour and it represents DFD m*e*at (O'Neill et al 2003). The colour can be measured objectively using a colour meter that is available commercially from a number of companies but this isn't used as much.

Figure *6* The colour scale used to determine pork quality (Godfrey, 2014)



Scores of 3,4,or 5 are considered ideal for palatability perspective. Scores of 1 and 2 are associated with the PSE condition. And finally a score of 6 is considered too dark for the consumer.

Drip loss is the final detrimental characteristic of PSE that can be measured to distinguish between normal and affected pork. Drip loss is the leakage of fluid from between the myofibrils of the meat and it has a significant economic impact due to the decrease in final overall weight of the carcass. Measuring drip loss involves collecting the fluid that leaks from the meat over a predetermined period of time and then calculating this as a percentage of the original weight. One method of measuring drip loss was described in a book that was a summary of a seminar in the CEC agricultural research programme in Dublin in 1985 titled the “Evulation and control of meat quality of pigs”.(Tarrant et al, 1985).

The drip loss was measured in a sample joint of betweem 400-600grams taken from the mid back region. The sample joint was weighed and placed in a net bag which was then suspended in a polythene bag from which most of the air was excluded. The bag containing the sample joint was then hung in a cold room at 1 degrees Celsius for 2 days after which time the amount of fluid collected in the bag was determined and the joint was dissected into lean fat and bone. The drip loss was calculated as a percentage of the initial sample joint weight and also as a percentage of the dissected lean meat.

Waste products of animal origin (Animal by products)

If pork is confirmed as being Pale Soft and Exudative it will not enter the human food chain and the abattoir must determine a suitable way to dispose of it or find another use that is both safe to the environment, and is economically viable. Waste products of animal origin or Animal by products (ABP's) are classified into 3 categories that are predetermined by the government. They are simply known as Category 1, Category 2 and Category 3.

Category 1 ABPs

Category 1 ABPs must be careful handled in order to prevent the potential spread of disease or damage to the surrounding environment.

Cat 1 material includes;

- carcasses and all body parts of animals suspected of being infected with TSE(transmissible spongiform encephalopathy)
- carcasses of wild animals suspected of being infected with a disease that humans or animals could contract
- carcasses of animals used in experiments
- parts of animals that are contaminated due to illegal treatments
- international catering waste
- carcasses and body parts from zoo and circus animals or pets
- specified risk material (body parts that pose a particular disease risk, e.g. cows' spinal cords)

Category 2 ABPs

Category 2 ABPs are classed as high risk material. They include:

- animals rejected from abattoirs due to having infectious diseases
- carcasses containing residues from authorised treatments
- unhatched poultry that has died in its shell
- carcasses of animals killed for disease control purposes
- carcasses of dead livestock
- manure
- digestive tract content

Category 3 ABPs

Category 3 ABPs are classed as low risk. They include:

- carcasses or body parts passed fit for humans to eat, at a slaughterhouse
- products or foods of animal origin originally meant for human consumption but withdrawn for commercial reasons, not because it's unfit to eat, this includes PSE pork
- domestic catering waste
- shells from shellfish with soft tissue
- eggs, egg by-products, hatchery by-products and eggshells
- aquatic animals, aquatic and terrestrial invertebrates
- hides and skins from slaughterhouses
- animal hides, skins, hooves, feathers, wool, horns, and hair that had no signs of infectious disease at death
- processed animal proteins (PAP)

PSE pork is classified as Cat 3 waste so the abattoir has a number of options to deal with it as the Cat 3 waste disposal guide lines dictate. The abattoir can send the pork for incineration or to a landfill after it has been processed although this is not economically viable as this will be a cost to the abattoir. There are a number of other options for example; processing and using to make organic fertilisers and soil improvers, using in composting or anaerobic digestion, applying to land as a fertiliser, in some cases, using as fuel for combustion or using to make cosmetic products or medical devices. None of these represent a viable option economically for the abattoir because they must wherever possible seek to minimise the cost of PSE Pork. So with that in mind the most viable option adopted by a number of abattoirs is the processing of the pork and using it to make pet food. This is carried out by a specialist pet food company that will usually buy other off cuts and offal from the abattoir for the same purpose (DEFRA, 2014).

Chapter Three

Case Study

A Case Study of an Irish Abattoir

Pig production is a valuable part of the agricultural industry in Ireland; it ranks third in importance behind beef and milk production. Employment in the pig sector accounts for at least 1,300 labour units on farms, with the total number employed in associated sectors such as pig meat processing, feed manufacture, haulage and services being estimated at 8,300. There is an estimated 290 commercial sow herds in Ireland, the June 2014 CSO Livestock Survey reported that there are 1.55 million pigs in Ireland, 151,100 breeding sows and 1,403,600 finishing stock (Agriculture and Food Development Agency, 2014).

A valuable market for the pork industry in Ireland is its export overseas; this is becoming a vital part of the industry. Those countries that Ireland export to have strict meat quality, hygiene and animal welfare standards as a result the issue of PSE pork and better welfare standards is of the upmost importance in the industry. In the first six months of 2015, Ireland exported 79,200 tonnes of pork, up 11 per cent on 2014 to a record level and this value reached €175.9 million. The overall increase was largely due to increased production of animals, with the total number of pigs in Ireland being killed up by 8 per cent in this period (The Pig Site News Desk, 2015).

In an attempt to discover the extent of the PSE problem in Ireland I decided to focus on one specific pig abattoir as I thought talking to vets and quality control inspectors on the ground would give the best insight into the issue. A number of potential locations in Ireland were researched with McCarren's of Cavan chosen as the most suitable location, the main reason being geographical location in relation to my home, the size of the plant and the fact that the vet in charge was willing to facilitate a tour of the factory and provide any information that may have been needed.

The McCarren family have been in the meat business for over 5 generations, the company has been trading successfully for over 90 years and as a result they are one of the oldest traditional pig-slaughtering and pig curing companies in Ireland. This company delivers a full range or pork and bacon from carcasses to full meat products. McCarren's believe that knowing the source of all their produce is vital in ensuring the quality of their final product

as a result around 90% of their meat is sourced within 20km of Cavan. The pig is killed and processed on site and the resulting meat is either sold in the farm shop or it leaves via its transport network for distribution through Ireland or for export abroad.

In 2013, meat processor Kepak bought a majority shareholding in McCarren's. Kepak Group, an Irish based company, is one of Europe's leading food processors dealing in a wide range of meat products not just pork. Kepak Group has a number of manufacturing facilities throughout Ireland and the UK, with sales offices in the key European and International markets. As of the 31st of March 2014 according to "top1000.ie" McCarren's has a €43.3 million turnover, a €1.4 million profit annually and it employs around 188 people although this figure may vary depending on the time of year (Irish Times, 2015).

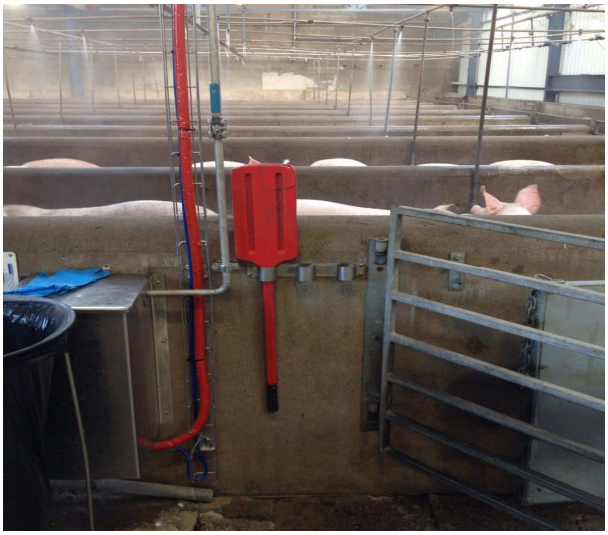
Figure 7 Mc Carrens Abittoir Co Cavan

On contacting the Veterinary officer in McCarren's a discussion was had around the abattoir business and how PSE affected the potential business. From the conversations over the phone Philip Sherridan the VO explained that PSE was not a major problem in this abattoir, he went on to say that he was not aware if the Quality Control Inspectors actually tested for the condition. Philip proposed a visit to the factory with a tour around providing an opportunity to speak with workers such the quality control inspectors and the manager in the boning hall who may have a greater knowledge of the PSE status.

This visit was facilitated by Philip the next week when a lengthy discussion took place around the issue prior to a tour of the premises. From the outset it was evident that the factory had high welfare standards, the pigs entering the plant were in good health. After the tour it was apparent that PSE does not occur on a regular basis in the factory probably as a result of a number of key factory policies. The priority on a daily basis was to ensure that the animals did not become stressed pre slaughter, post slaughter practices also helped to nullify the potential problem of PSE.

The fact that almost 90% of the pigs slaughtered by McCarren's are produced within a 20Km radius of the factory is a major bonus. This reduces transport time from the farm to the abattoir to 60 minutes maximum which inevitably reduces the possibility of stress. For those pigs which come from outside of County Cavan they could have a travel time of up to 4-5 hours. The DVO in Cavan do carry out strict welfare checks on transport vehicles and the pigs themselves before they are transported. Cavan is close to the Ireland North South border on the southern side, due to its location pigs are regularly exported cross border to be slaughtered. If animals are exported the local VI in charge of the area where the animals originate will carry out an inspection of the vehicle and the animals before transportation and all the drivers' documentation will be checked. In the South of Ireland if animals are to be transported for a distance greater than 65Km a specific set of documentation that state that the driver has completed the necessary training and that he/she is competent to transport animals for longer than a distance of 65Km is needed, without this documentation the animals may not be transported. The local VI's in the Cavan DVO also carry out regular welfare inspections on the pig farms in the area so if there are any concerns the staff in McCarren's can communicate with the DVO regarding issues around the welfare of the pigs that they slaughter.

Figure 8. The 'paddle' used to move pigs in Mc Carrens



McCarren's have a system where the lorry is weighed with the pigs on board as soon as they arrive at the factory this weight is recorded, when the pigs are unloaded the lorry is weighed again, the calculated difference in weight before and after is taken as the weight of the pigs. The factory have an agreed "kill out percentage" with the farmer of 75%, the farmer gets paid for 75% of the total weight of the pigs. All lorries arriving at the factory are given time slots resulting in the fact that no lorry has to wait an excessive amount of time to be unloaded; unloading is carried out by a member of the lairage staff assisted by the driver.

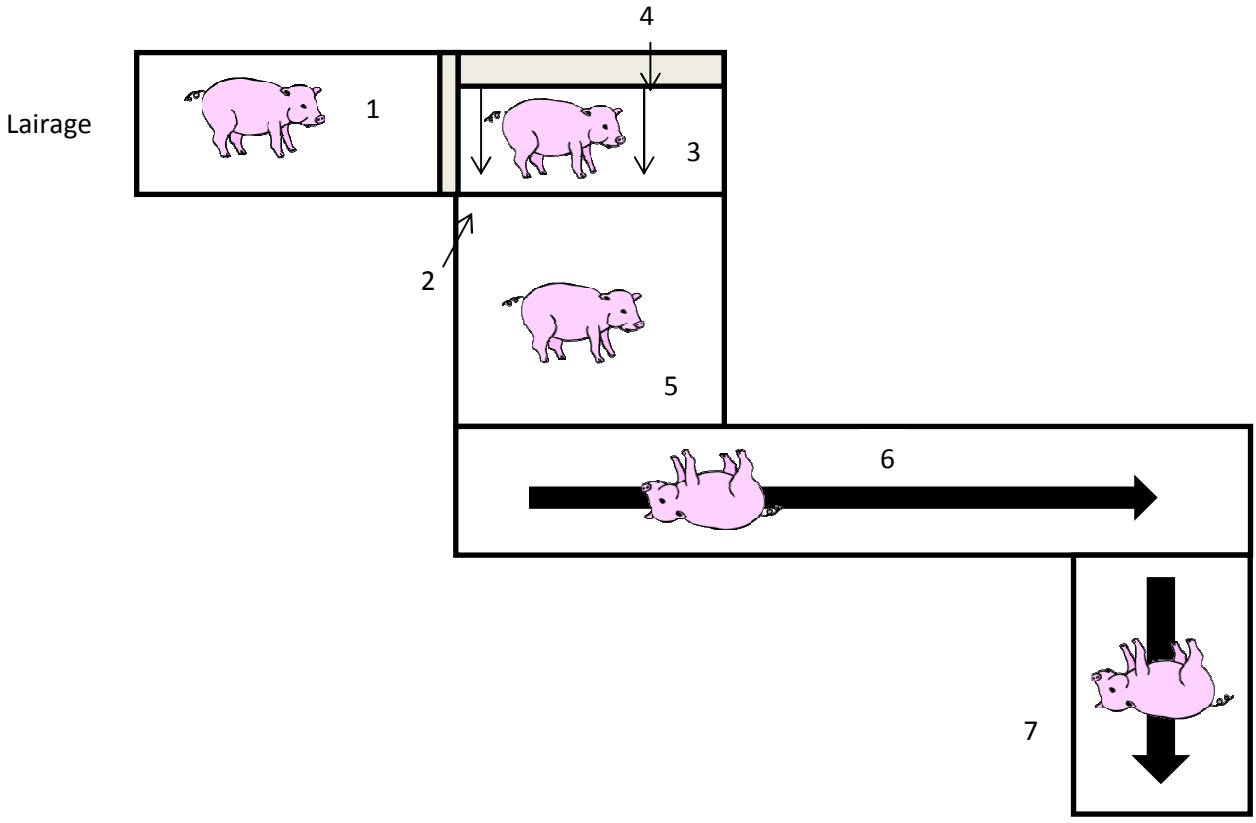
Figure 9. The unloading bay for pigs at Mc Carrens lairage

Upon entering the lairage the most striking thing was the quiet atmosphere, there was no shouting, no banging gates shut or distressed pigs being vocal, in fact there were a number of pigs sleeping in the lairage which was a sign of just how relaxed and at ease they were. The pigs were unloaded in groups of 10-12 and were moved gently by the lairage staff into a holding pen, they were moved along using boards or paddles which were better for the pig's welfare. As mentioned all the pigs in the lairage were very relaxed with no obvious signs of stress. According to the VO Philip Sherridan there was no predetermined rest time for the pigs on entering the lairage however due to the queuing process in the lairage pigs were usually around 1-1.5 hours in their pens before they were slaughtered. Pigs were accepted into the lairage from 8-8.30 am and no animals were killed until 10am, this delay was due to the fact that the carcasses from the previous day were still in the chillers as the abattoir likes to cool the carcasses for the longest time possible. As each lorry load of pigs are put into their pens the staff present turn on the water sprinkling system in the lairage, this sprays water over the pens and onto the pigs these sprinklers are usually turned off manually after a few minutes. In most literature it suggests that this is vital to reduce the body temperature of the pigs post transport, but the VO suggested that the main aim of spraying the pigs with water in his opinion was to clean them post transport. The issue of overheating during transport in Ireland is not as big a problem as it may be in other countries due to the climate. The average maximum January temperature in Cavan is 8.0 °C (46 °F), while the average maximum July temperature is 19.1 °C (66 °F) (Keane, 2012). A temperature in the early 20's does not cause a problem in a well ventilated lorry during a short journey.

Figure 10.The water sprayers in the lairage

McCarren's had installed a new Co2 stunner a few months previous to the visit, all the staff agreed that the new stunner was very effective, it significantly reduced the stress experienced by the pigs during stunning as they kill around 7000 pigs a week, with this volume Co2 stunning was the only really viable option. The stunner was manufactured by a company called Butin who manufacture a range of stunners varying in size; they claim it is possible to stun 500 pigs per hour or more if the larger models are used with properly trained staff. Electrical stunning was considered too slow and it can if not done properly induce unnecessary stress in the animals. The general concept of the stunner is; the pigs arrive at the stunning system, they are brought into the stunning box in groups of 5 to 9, the box is lowered into the CO2 atmosphere until the anaesthesia is sufficient to shackle and stick the pigs before they return to consciousness.

Figure 11. Diagram explaining how the Co2 stunner works



The pigs are taken out of their holding pens in the lairage by a member of staff in groups of 5-9 because this is thought to keep the pigs calmer and it is also more time efficient. The pigs are then put into a holding pen just before the stunner (1), as mentioned previous the staff only use pig boards or paddles to move the pigs no shouting or hitting of the pigs is permitted. Once the pen directly outside the stunner is free a roller door opens (2) and the pigs move into the pen (3) the roller door is virtually silent and it is opened by a button outside the pen which means the pigs have minimal contact with the staff and there are no loud noises. The door to the stunning box then opens (5) and the side wall of the holding pen (4) directly outside the stunning box moves to usher the pigs into the stunning box, again this is a stress free way of moving the pigs. The door closes in the stunning box and the pigs are then exposed to 80-90% carbon dioxide for 90 seconds. After this the back door of the stunner opens and the pigs that are incapacitated at this stage fall onto a conveyor belt (6) which brings them to the point of shackling and sticking (7). McCarren's aim to stick each pig within 45 seconds of stunning to ensure that no pig would regain consciousness, this policy was strictly adhered too, the fact that there was 5-9 pigs being stunned at a time this target of 45 seconds was achievable. The member of staff at the shackling point does have a captive bolt if they judge that a pig is not sufficiently stunned for sticking although this rarely happens.

Figure 12.The stunned pigs moving out of the stunner onto the conveyor belt to the 'sticking' point.

Figure 13. The holding pens for the pigs before the stunner

After sticking, the pigs are allowed some time to bleed out and then they pass on into the scalding area. The pigs pass through a water bath which runs at about 60 degrees centigrade to soften the hair, they then pass through a flailing machine to remove the hair. From here they pass into a singer which burns off any excess hair still remaining on the carcass, the carcass then passes through a flailing machine again, it then passes from the "dirty" area into the "clean" area. The "clean" area is where the evisceration takes place and the carcass is split in two. After evisceration and the veterinary inspector check the carcasses, they then move into the chillers where they are chilled to 3-5 degrees centigrade until they are processed the following day.

All carcasses are processed on site at McCarren's. The half carcasses are moved from the chiller into the boning hall where they are butchered into the different pieces, some of the prime cuts are sold fresh out of the factory but the majority of the other cuts are processed and blast frozen and then distributed throughout Ireland and beyond. On discussion with the manager of the boning hall the question as to the prevalence of PSE in the abattoir arose, he said he did find a small amount of PSE pork in and around the femur whilst deboning however it was minimal and since the installation of the new Co2 stunner he confirmed that he very rarely, if ever seen PSE.

The roll of the quality control inspectors within the factory is to ensure that the correct operating procedures are followed by all the staff, on a regular basis they also monitor the prevalence of certain pathogens in the factory for example Salmonella or in some cases the investigation of antibiotic residues in carcasses. On speaking with the head of the quality control in the abattoir in relation to her role with regard to PSE monitoring she suggested it was not an issue therefore she did not measured for it regularly. In the month previous however she had started to measure the pH of carcasses in the abattoir, but this was because the firm were looking to expand their export market and measuring the pH was to satisfy the guidelines set by the American market not to monitor for PSE. This measurement took place on the first five carcasses each day, so the data that they had collected to date has no real scientific value. Following the visit to this factory I decided to extend the scope of the study in an attempt to have a decisive conclusion as to whether PSE was indeed a problem anymore in Ireland. Cookstown Pig abattoir in Northern Ireland and the Ministry of Agriculture Veterinary Laboratory in Belfast were both contacted to ascertain if their experiences were similar to that of McCarren's.

Chapter Four
Conclusion

Conclusion

Pig farming and the pork industry as mentioned previously forms an important part of the Irish economy. As this industry continues to grow the production standards continue to improve. It has become evident through this study that PSE is no longer the major issue in Ireland that it may have been in the past due to higher welfare standards and the continuing improvements in farming practice.

The main change to pig farming practice in the last number of years which may have had the greatest impact on the reduction of PSE is the improvement in the genetic makeup of the pigs. The Veterinary Inspectors attached to the abattoirs in Ireland confirmed that PSE was a problem in the past however this is no longer the case, they cited the continued improvement of genetics of the pigs that are farmed in Ireland as the most probable reason for this. One of the vets in the Ministry of Agriculture Laboratory identified the Duroc breed as a source of the defective gene for PSE in pigs in Northern Ireland, she went on to say that the modern hybrids in Northern Ireland currently have a very low proportion of Duroc in their genetic makeup although in some hybrids the use of the Duroc breed is being increased because of their high performance characteristics when it comes to weight gain and leanness. This increased use of the Duroc breed may in the future lead to another rise in the prevalence of PSE in Ireland. The increased welfare standards throughout the production of the pigs from when they are born until they are slaughtered also has a positive effect in reducing the incidence of PSE although if the pigs have a genetic predisposition to PSS it would seem that irrespective of the welfare standards the pig will more than likely succumb to PSS and the resulting pork will have the PSE characteristics.

The improvements in welfare standards throughout Ireland since the 50's has been well recognised and in the opinion of many of the veterinarians that I spoke to during this study it is no coincidence that there is a positive correlation between the improvement of welfare standards and the fall in PSE in the Irish pork industry. McCarran's was the abattoir of choice in this study; the overall welfare standards of the pig from lorry to slaughter in their factory were excellent. Most of the good welfare practices that were adopted seemed to have been enforced by the vets in the department of Agriculture and the overseas

customers that McCarren's were hoping to export their final product to, not by the abattoir themselves, this is a positive thing as it ensures that welfare standards remain high. Originally these practices would have been implemented to reduce stress in the pigs and the resulting decrease of quality because of PSE, but there seems to have been a shift in focus in the industry in Ireland from high welfare standards to reduce the loss of profit caused by PSE to an increase of welfare standards to enhance the pigs quality of life and to ensure the pigs do not suffer any unnecessary stress pre slaughter which must been seen as the most desirable outcome.

Chapter Five

Summary

Abstract

Introduction: Pork is one of the world's most popular meats with over 80 million tonnes produced annually. Pork output in Ireland increased by over 90% in the period from 1988 to 2002 and has been stable since then**.** As a result any decrease in quality has a major impact on the Irish economy. In this study the quality defect of PSE was investigated and its prevelance and economic impact in Ireland was determined.

Aim of Thesis: To investigate the extent of the problem of Pale Soft and Exudative pork meat in Ireland through a study of an Irish abattoir, paying particular attention to its operating procedures to determine if they have any influence on the incidence of PSE.

Litrary review: In the literay review the disease of PSS and the resulting PSE pork is reviewed in detail and the contributing factors causing its prevelance. There are many contributing factors that can lead to PSE in pork, from the genetic background of the disease to the handling of the pigs immediately before slaughter.

Case study of an Irish Abattoir: In an attempt to discover the extent of the PSE problem in Ireland I decided to focus on one specific pig abattoir as I thought talking to vets and quality control inspectors on the ground would give the best insight into the issue of PSE in Ireland.

Conclusion and Findings: It has become evident through this study that PSE is no longer the major issue in Ireland that it may have been in the past due to higher welfare standards and the continuing improvements in farming practice. The main change to pig farming practice in the last number of years which may have had the greatest impact on the reduction of PSE is the improvement in the genetic makeup of the pigs. The improvements in welfare standards throughout Ireland since the 50's has been well recognised and in the opinion of many of the veterinarians that I spoke to during this study it is no coincidence that there is a positive correlation between the improvement of welfare standards and the fall in PSE in the Irish pork industry.

List of Figures/Diagrams

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