

**The effect of pale, soft and exudative (PSE) pork
on the sensory quality characteristics of low fat
bacon**

by

MOSHADIWA GERMINA MOKWENA

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**Department of Food Science
Faculty of Natural and Agricultural Sciences
University of Pretoria**

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Who encouraged me to study, supported me when I did and cheered when I did well.



I declare that the dissertation herewith submitted for the M Inst Agrar (Food Production and Processing) degree at the University of Pretoria, has not been previously submitted by me for a degree at any other University.

ABSTRACT

The effect of pale, soft and exudative (PSE) meat on the sensory quality of low fat bacon

Candidate: Moshadiwa Germina Mokwena

Leader: Dr H.L. de Kock

Co-Leader: Prof. A. Minnaar

Department: Food Science

Degree: M. Inst. Agrar (Food Production and Processing)

This research focused on studying the sensory quality of low fat bacon when pale, soft and exudative (PSE) pork is used during processing. Low fat bacon is different from normal bacon in that the amount of visible fat in low fat bacon has been reduced. This is as a result of consumer interest in weight control and cholesterol, creating a demand for meat and meat products with reduced fat levels. PSE pork is a condition in which certain muscles are very pale, soft and watery. It is produced when the rate of post-mortem glycolysis is fast and a high level of acidity is reached while the carcass temperature is still high. Different researchers have reported that PSE pork absorbs less brine during curing and this may have a negative effect on the sensory quality and acceptance of both the uncooked and cooked finished products as it is mainly the curing brine that is responsible for the development of the typical colour, flavour, aroma and texture associated with cured meat products.

Thirty pig carcasses, 15 PSE and 15 normal pH, suitable for production of low fat bacon, were selected over a period of three weeks at an abattoir in Olifantsfontein to study the effect of PSE meat on the sensory quality of low fat bacon. The carcasses were further processed into low fat bacon at a meat processing plant. Data were collected on the % brine uptake of PSE and normal pH meat after curing; the rating scores on the descriptive sensory attributes of both PSE and normal pH low fat bacon and the % salt

concentration and residual nitrite of PSE and normal pH low fat bacon. A consumer test to determine the buying preferences for packaged PSE and normal pH low fat bacon and the eating quality preferences of cooked PSE and normal pH low fat bacon was also conducted.

No significant difference ($p > 0.05$) was found in the % brine uptake between PSE and normal pH meat. There were no significant differences ($p > 0.05$) in the descriptive sensory attributes of PSE and normal pH low fat bacon. The residual nitrite concentration of normal pH low fat bacon was significantly higher than that of PSE low fat bacon. There was however no significant difference ($p > 0.05$) in the % salt concentration of PSE and normal pH low fat bacon.

Correlation matrices showed significant positive correlations ($p \leq 0.05$) between % brine uptake and % salt concentration and between % salt concentration and perceived saltiness of normal pH low fat bacon. For PSE low fat bacon, the correlations between % brine uptake and % salt concentration and between % salt concentration and perceived saltiness was not significant. The correlation between % brine uptake and residual nitrite content was however not significant ($p > 0.05$) for both the PSE and normal pH low fat bacon.

A significantly higher number of consumers indicated that they would prefer to buy samples representing PSE low fat bacon. The pale colour of PSE meat was not masked after curing, which was noticed by the consumers during the evaluation of buying preferences for PSE and normal pH packaged low fat bacon. However, regarded as even more important than colour, the consumers mentioned fat content as the main deciding factor for purchasing low fat bacon. No significant difference ($p > 0.05$) was found in the preference for the eating quality of cooked PSE and normal pH low fat bacon.

It was concluded that PSE meat can successfully be used to produce low fat bacon products of consistent quality. This conclusion is drawn from the

analytical sensory test results, where the use of PSE meat did not affect the sensory quality characteristics of low fat bacon. For low fat bacon, fat content is an important factor, regarded as very influential to consumers when making purchases. It is therefore important to produce products with consistent fat content according to specifications.

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CHAPTER 1: INTRODUCTION

The success of any food product is determined by consumer satisfaction, which is largely determined by the perception of quality (Dransfield, 2001). Product quality improvement must be driven by the consumer's expectations and perceptions (Issanchou, 1996). According to McGill (1984), the two most accepted definitions of quality are "fitness for use" and "conformance to specifications". For meat, the quality properties of most concern are colour, texture and flavour (Naudé; cited by Strijdom, 1989). The eating quality of meat can be defined in terms of the sensory attributes of colour, tenderness, juiciness and flavour, which are the principal determinants of the acceptability of meat products to consumers (Jeremiah, 1982).

In the development of the sensory properties of meat products, the quality of raw meat to be used is of primary importance (Gil, Guerrero & Sarraga, 1999) as it influences the quality of the final products (Toldrá, Flores & Sanz, 1997). Pork quality is essentially synonymous with the condition known as pale, soft and exudative, identified by the term PSE (Cassens, 2000). The terms reflect the appearance and physical condition of the meat. Of importance, is the fact that PSE pork has limited value for further processing (Cassens, 2000).

Enterprise foods, Germiston contracted the Department of Food Science, University of Pretoria to study the effect of pale, soft and exudative (PSE) pork on the sensory quality of low fat bacon. This was as a result of problems related to the inconsistent quality of the final product, in terms of appearance, that they were producing at the time. The poor quality of the low fat bacon led to rejection of the product by consumers due to dissatisfaction.

For the purpose of this study, low fat bacon refers to bacon in which the fat content has been reduced. This is important in selecting breeding animals. The selection would be for the reduction in the fat to muscle ratio and marbling content, not taking into account meat quality characteristics.

For this study, pork meat quality traits were categorised as (1) visual quality characteristics and (2) eating quality characteristics, also referred to as meat product palatability (Miller, Moeller, Goodwin, Lorenzen & Savell, 2000). Visual pork quality characteristics have been defined as water holding capacity or drip loss, lean colour, back fat thickness, pH (as it relates to drip loss and colour) and intramuscular fat or marbling.

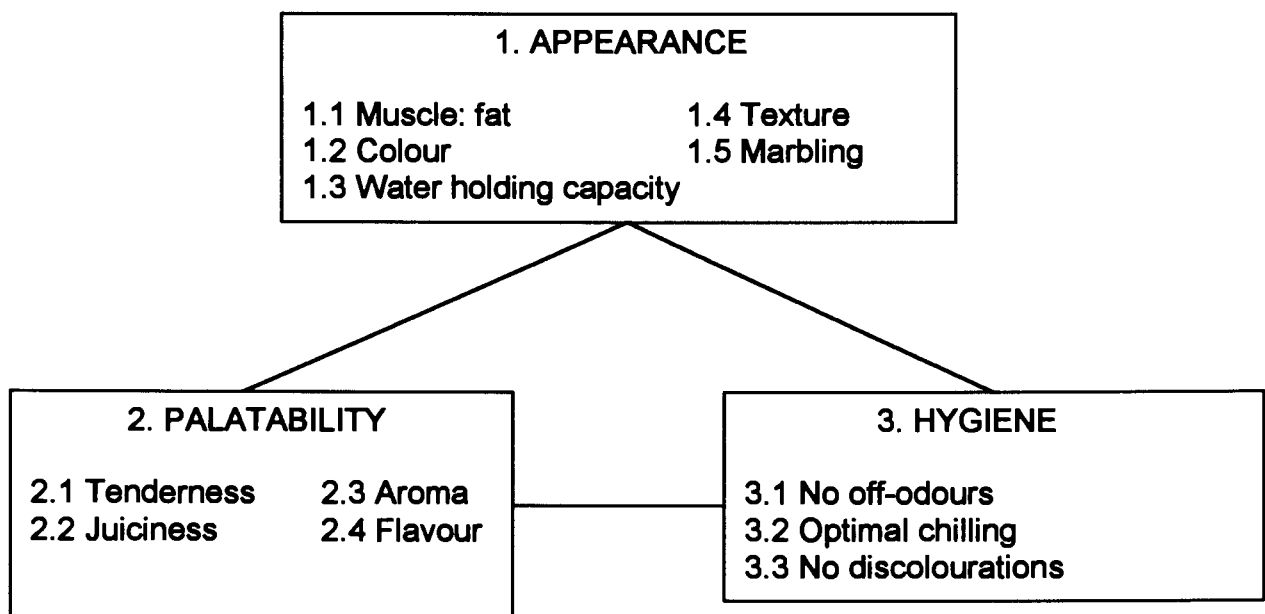


Figure 1: Selected components of meat quality (Naudé; cited by Strijdom, 1989).

CHAPTER 2: LITERATURE REVIEW

2.1 QUALITY DEFECTS IN RAW PORK FOR BACON PROCESSING

The major problems of pork meat quality are caused by abnormal changes in the carcass after death (Sunderland, 1991). This begins when the muscles are no longer supplied with oxygen. Instead of being oxidised into energy, glycogen in the muscle is converted to lactic acid. Post mortem glycolysis, the metabolic conversion of glycogen to lactic acid, is responsible for the lowering of pH in muscles due to the accumulation of lactic acid (McKeith, Lan & Beerman, 1994). Living muscle maintains a pH of approximately 7.4 and depending on the amount of glycogen present in muscle at death, the pH may drop to an ultimate level of 5.5 to 5.7.

The acidity of the muscle indicates the development of rigor. Rigor mortis is a temporal process occurring during the time course of post mortem glycolysis and is characterized by progressive stiffening of the muscles (Faustman, 1994). The loss of adenosine triphosphate (ATP) during post mortem anaerobic glycolysis is the event causing the onset of rigor. Post mortem changes may vary causing two problems, namely, pale, soft and exudative (PSE) and dark, firm and dry (DFD) meat, the latter which is normally visible in beef and rare in pork. Fernandez, Forslid & Tornberg (1994), reported that PSE meat is the most important quality defect of pork.

PSE pork is a condition in which certain muscles are very pale, soft and watery (Owen, Montgomery, Ramsey & Miller, 2000). It is associated with a rapid rate of post mortem glycolysis, resulting in a pH below 6.2 while the carcass is still at a high temperature of 36 – 40 °C (Figure 2). The PSE condition therefore develop as a result of the very early post-mortem changes as muscle is converted to meat (Cassens, 2000).

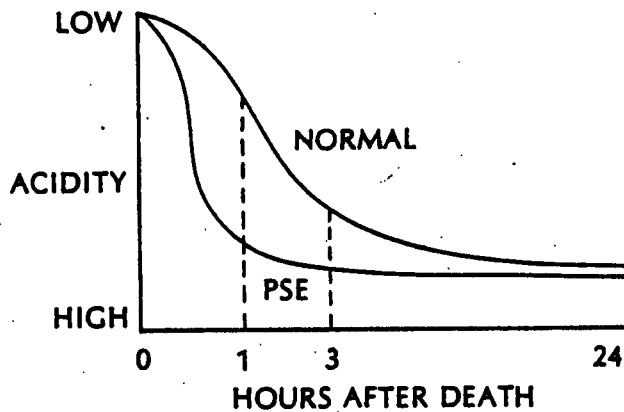


Figure 2: The rapid drop in pH of the muscle in the early hours after death while the temperature of the carcass is still high, resulting in PSE pork (Sunderland, 1991)

PSE meat is produced when the rate of post-mortem glycolysis is fast and a high level of acidity is reached while the temperature is still high (Sunderland, 1991). The high acidity causes some protein damage which affect the structural components of the muscle, giving it a pale, unattractive appearance. It also causes the muscle proteins to denature leading to lowering of the water holding capacity and surface tension of the meat. Honikel & Kim (1986) reported that previous studies associated with PSE showed that increased drip formation is caused by the denaturation of both myofibrillar and sarcoplasmic proteins which predominantly occurs early post mortem when the pH is low and the temperature is high. These explanations are in agreement with the results by Fisher, Mellet & Hoffman (2000), who reported that the low water holding capacity typical of PSE meat was due to extensive protein damage.

The degree of protein denaturation is dependent on the rate of the pH fall up to the onset of rigor. According to Honikel & Kim (1986), the myoglobin of PSE prone pigs is also more unstable and prone to denaturation by heat. Both of these factors result in a loss of the red colour, aiding in the development of the paleness of PSE muscle.

2.2 PRACTICES AND FACTORS THAT MAY LEAD TO THE DEVELOPMENT OF PSE PORK

2.2.1 Ante-mortem factors

The term ante-mortem refers to all the procedures and activities which are carried out prior to slaughtering (Warriss, 2000). The metabolic systems of the pig are at this stage still active. Stress susceptibility, transport and lairage, mixing of unfamiliar animals and temperature are some of the ante-mortem factors that play an influential role in determining the quality of raw meat for processing.

2.2.1.1 Stress susceptibility

Traditionally, pigs have been classified as being stress resistant and stress susceptible, usually by using the halothane test (Sunderland, 1991). Pigs carrying the halothane gene are more susceptible to stress pre-slaughter, resulting in an increased incidence of PSE pork. Three genotypes are found: NN, Nn and nn genotypes. In their study, Channon, Payne & Warner (2000), found higher incidence of PSE in Nn pigs compared to NN pigs. This was accompanied by lower sarcoplasmic protein solubility and increased percentage drip loss and purge.

These results are in agreement with the report by Leach *et al.* cited by Channon *et al.* (2000), that pigs that are heterozygous (Nn) for the halothane gene, are four times more likely to produce PSE pork than homozygous negative (NN) pigs as they are more susceptible to stress. The development of the PSE condition can result from acute stress immediately prior to slaughter which causes rapid glycolysis in pork muscle, resulting in a rapid fall in muscle pH while the carcass temperature is still high.

2.2.1.2 Transport and lairage

The main purpose of lairage is for the abattoir to maintain a constant throughput of pigs (Sunderland, 1991). Pre-slaughter handling of pigs during transportation and lairage causes physical and emotional stress which will influence muscle metabolism and ultimately meat quality (Warriss, 1987). Various stress factors are involved in the transportation of pigs from the farm to the abattoir. Such factors include unfamiliar noise and odours, deprivation of food and water, vibrations, changes in acceleration and fighting (Fernandez & Tornberg, 1991).

Warriss (1987) demonstrated that higher stocking densities during transportation resulted in evidence of more physical stress. According to Fernandez & Tornberg (1991), increased lairage time leads to a depletion in muscle glycogen and a resulting increase in ultimate muscle pH. This can be attributed to chronic stressful events such as environmental changes, mixing of animals, fighting and food deprivation which occur during this period.

2.2.1.3 Mixing unfamiliar animals

An important consequence of mixing pigs from different rearing groups during transport and in lairage is that they often fight (Warriss, 1987). This leads to unsightly lacerations on the skin. In bacon carcasses, this may lead to down-grading as they are unsuitable for production of rind-on bacon. Even when the severity of fighting damage is insufficient to cause down-grading, other consequences may be economically important. The physical exertion may deplete muscle glycogen stores and if the stress occurs immediately pre-slaughter, it may increase the incidence of PSE meat.

2.2.1.4 Temperature

Faustman (1994) reported an increase in the incidence of PSE in summer to almost double that during spring in an abattoir in Portugal. This can be attributed to higher environmental temperature. Klont & Lambooy (1995) refer to various research results regarding the importance of initial temperature in determining the rate of post mortem muscle metabolism and subsequent meat

quality. The authors stated that pigs kept under stressful temperature conditions showed an increase in muscle temperature, which is associated with other physiological disturbances liable to affect muscle metabolism, such as changes in respiratory and circulatory parameters, as well as circulating stress hormones.

2.2.1.5 Stunning

Pigs may be given a good treatment from farm gate to the abattoir lairages, be transported in air conditioned ease, but all this care and solicitude for the pigs will be of little avail in terms of control of muscle biochemistry and control of meat quality, if stunning and sticking are inefficiently or incorrectly carried out (Ratcliff, 1971). The shock sustained at slaughter may counteract the beneficial effect of careful handling of the pigs prior to slaughter and as a result the pH of the meat may range from 7.0 down to 5.4, with a variable proportion of the carcasses showing pale and watery meat.

The purpose of stunning is to render the animals insensitive to pain until death intervenes. Van der Wal, Engel & Reimert (1999) mentioned that treatment of pigs shortly before stunning, as well as the stunning procedure, affect ultimate pork quality even when the pigs were moved gently from the lairage to the stunning pen. A bad stunning technique is associated with a rapid drop in pH, but even optimum stunning methods can be characterized by a wide variation in the rate of metabolism post-mortem (Hessel-de Heer, Sybesma & Van der Wal, 1971).

2.2.2 Post-mortem factors

Post mortem factors are all those factors which take place after the death of the animal (Warriss, 2000). All the processes after the carcass has been finally cleaned can be regarded as post mortem. Post mortem temperature will influence the quality of the meat. Of critical importance is the temperature used to chill the meat.

2.2.2.1 Post-mortem temperature

Fernandez *et al.* (1994) reported that temperature plays an important role in PSE development even though muscles exhibit normal rates of post mortem pH fall. Van der Wai *et al.* (1997) proved that elevated muscle temperature in the early post mortem period can contribute to the development of PSE. Because of this negative effect of high muscle temperature early post mortem, heat supply should be limited to a strict minimum shortly before killing and early post mortem in order to allow a fast decrease in muscle temperature. Thus any factor which affect the rate of temperature decline in the carcass have the potential to cause PSE, e.g air circulation flow, insufficient spacing between carcasses and overstocking of chillers.

2.3 CONSEQUENCES AND ECONOMIC SIGNIFICANCE OF PSE MEAT FOR FURTHER PROCESSING

PSE musculature in pork has been recognised as of importance in the meat industry as it results in great practical difficulties in the fresh meat trade, as well as the manufactured meat trade (Cassens, 1994; Arnau, Guerrero, Casademont & Gou, 1995). Consumers are becoming more discriminating and will no longer accept meat of inferior quality (Cassens, 2000). Furthermore, PSE meat has limited value for further processing.

The lower water holding capacity of pigs affected by PSE (Arnau *et al.*, 1995) is reflected in their reaction to curing (Lawrie, 1979). Meat from muscles in which post-mortem glycolysis was fast and in which the structure is watery, has a poor absorption of the curing brine compared with normal meat (Fisher *et al.*, 2000). This may greatly influence the sensory quality of the cured meat products.

PSE meat have been shown to produce twice as much drip as normal meat, resulting in a 1 % yield loss of fresh meat. It obviously have serious economic implications for the meat processing industry (Arnau *et al.*, 1995; Fisher *et al.*,

2000). Honkavaara (1988) also found high economic losses as a result of the commercial use of PSE meat in cooked ham manufacture.

Pigs with a tendency of producing PSE musculature have been found to have thinner backfat (Paterson, cited by Pearson & Gillett, 1996). Pork with thinner backfat results in the splitting of the fat and it causes difficulty in slicing sides leading to non-uniform end products. The separation usually takes place between the different backfat layers, between backfat and muscle and between intramuscular fat and muscle (Wood, 1985). Thinner backfat layers have a larger percentage of unsaturated fatty acids leading to higher thiobarbituric acid (TBA) values, indicative of rancidity, even after frozen storage.

2.4 BACON PROCESSING

The following (Figure 2), is an example of a typical flow diagram for the production of bacon using injection wet curing

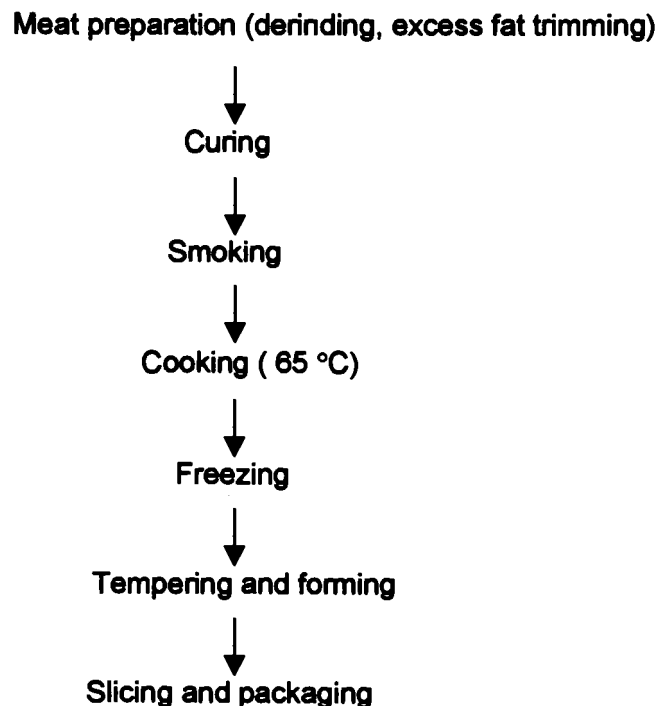


Figure 2: A typical production process for the manufacturing of bacon (Agricultural Research Council-Animal Nutrition & Products Institute, 1999).

2.4.1 Curing

Curing refers to a modification of the meat and it affects preservation, flavour, colour and tenderness (Kramlich, Pearson & Tauber, 1973). Originally, curing treatments were practised as a means of preserving meat before the days of refrigeration. In less developed areas without modern preservation facilities, the prime objective of curing still is preservation. However, where more effective preservation methods are available, the prime purpose of curing is to produce uniquely flavoured meat products and to preserve the red colour of meat after cooking.

The principal ingredients used for curing meat are (1) salt, which is a mild preservative and adds flavour; (2) sodium nitrate and sodium nitrite, which are preservatives having anti-microbial activity notably against *Clostridium botulinum* and are red colour fixatives; (3) sugar, which helps stabilize the colour and also adds flavour; (4) spices, which are mainly for flavour and (5) curing accelerators (Kramlich *et al.*, 1973). Other ingredients are water and phosphates.

2.4.1.1 Salt

Salting is one of the oldest methods used for meat preservation (Gray, Macdonald, Pearson & Morton, 1981). Salt acts by lowering the water activity and by altering the osmotic pressure so that it inhibits bacterial growth and subsequent spoilage (Kramlich *et al.*, 1973). Salt also gives flavour and increase the protein solubility (Macrae, Robinson & Sadler, 1993). The purity of salt used in curing is important (Cassens, 1994). Possible contaminants such as metal ions may have an undesirable effect, for example, in promoting oxidative rancidity of the meat products.

2.4.1.2 Sodium nitrate and sodium nitrite

Sodium nitrate and sodium nitrite are unique ingredients in meat curing systems because of their ability to produce the characteristic cured meat colour and to generate the typical cured meat flavour (Ramarathnam, Rubin &

Diosady, 1991). When sodium nitrate is used in combination with sodium nitrite, it is reduced to nitrite by microorganisms (Cassens, 1994). This is because nitrite is the active chemical ingredient that reacts with the meat pigment myoglobin, to produce a desirable colour. The ability of microorganisms to reduce nitrate (Figure 3) in bacon brines is one of the metabolic activities found among the bacteria capable of growing at high salt concentrations (Lawrie, 1991).

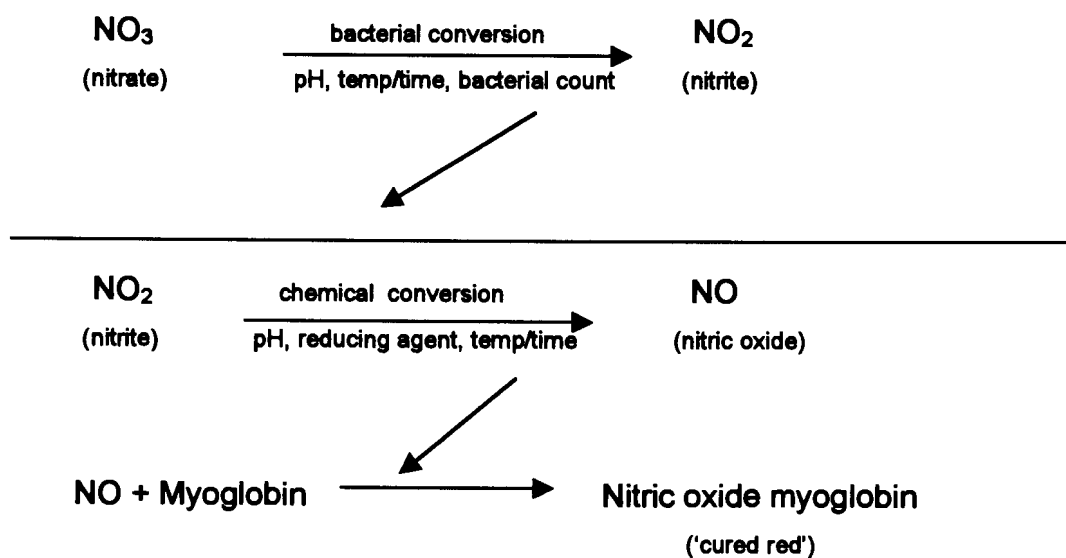


Figure 3: The series of reactions that leads to the formation of cured colour (Honikel & Kim, 1986).

The other functional contribution of nitrite to cured meats is that it has an antimicrobial effect that is important in the prevention of *Clostridium botulinum* outgrowth, particularly under conditions of product mishandling (Cassens, 1994). This is the reason why nitrates and nitrites are considered essential in producing safe cured meat products (Macrae *et al.*, 1993). Nitrite act by lowering the temperature required to kill *Clostridium botulinum* and it inhibits germination and outgrowth of its spores. It also has adverse effects upon the growth of *Clostridium perfringens* and *Staphylococcus aureus* as well as other non-pathogens under conditions of meat storage.

Foods are susceptible to quality losses due to chemical reactions. Oxidation of lipids is one of the most significant causes of deterioration. Jeremiah, Ball, Uttaro & Gibson (1996) mentioned that nitrite prevented lipid oxidation through the formation of complexes with iron porphyrins. The authors reported that nitrite reacts with the haem iron in the unoxidised ferrous form to prevent the formation of ferric iron which is in the oxidised form and considered the most important catalyst in meat for lipid oxidation. This reaction probably accounts for the prevention of “warmed-over” flavour, another form of oxidation, in cured meats (Gray & Pearson, 1987).

The other potential nitrite reaction involves the flavour contribution attributed to nitrite. There is general consensus that nitrite leads to a modification of the fresh meat flavour (Gray & Pearson, 1987; Price & Schweigert, 1987). The nature of this flavour component however is totally unknown and no specific reactions have been hypothesized.

A potential major problem is the possibility that nitrite reacts with secondary amines which are naturally present in meat to form nitrosamines (Figure 4) which as a class of compounds are known for their carcinogenic properties (Cassens, 1994).

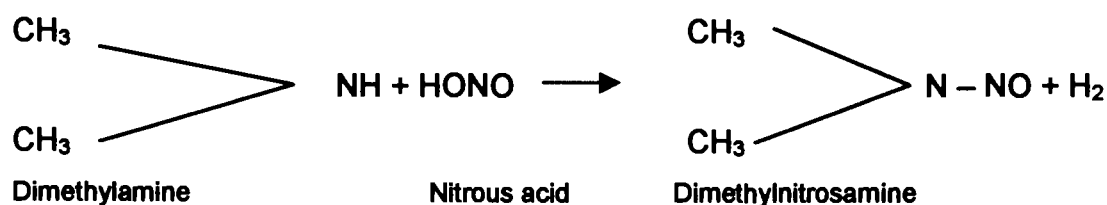


Figure 4: Nitrosamine formation (Cassens, 1994).

2.4.1.3 Sugar

The addition of sugar to cures is primarily for flavour (Desrosier & Desrosier, 1977). Sugar softens the products by counteracting the harsh effects of salt, preventing some of the moisture removal and by direct moderating action on flavour. Sugar also interacts with amino groups of the proteins and, upon

cooking, forms browning products which enhance the flavour of cured meats (Macrae *et al.*, 1993). The type of sugar used may influence colour development (darkening or browning) as the meat is exposed to heat during preparation (Cassens, 1994). The amounts of sugar used are just enough to give flavour and are not sufficient to exert a preservative effect.

2.4.1.4 Spices

Spices are added to give a characteristic flavour (Cassens, 1994). They are not generally recognized as providing a preservative effect, with the possible exception that some may contain naturally occurring antioxidants.

2.4.1.5 Curing accelerators

Curing accelerators are used primarily to speed up the curing process and to make it more uniform (Cassens, 1994). Curing accelerators act by reducing the brown pigment, metmyoglobin, to myoglobin which is red. They also promote the formation of nitric oxide (NO) from nitrous acid (HONO). Ascorbic acid is an example of a curing accelerator frequently used in curing. It is a powerful reduction agent, releasing nitric oxide from nitrite (Wirth, 1986). With the larger supply of nitric oxide, a larger quantity of myoglobin is accelerated into nitric oxide myoglobin ('cured red'). The curing process is therefore accelerated and intensified.

2.4.1.6 Phosphates

Phosphates have many functions in meat products; however, one of the greatest benefits is the improvements in water holding capacity (Claus, Colby & Flick, 1994). Processing yields are significantly improved and purge accumulation in the package during storage is reduced with the use of phosphates. Meat products formulated with phosphates retain more natural juices and added water during heat processing and subsequent re-heating.

Phosphates have the ability to chelate certain metal ions (Claus *et al.*, 1994). This function may be of benefit as traces of iron and copper can act as catalysts in lipid oxidation. As such, phosphates can have a role in flavour preservation in addition to maintaining product appearance and colour.

2.4.1.7 Water

Water, one of the most common non-meat ingredients, has many vital functions in processed meats including assisting in ingredients distribution, solubilization of meat proteins and improvement of various sensory traits (Claus *et al*, 1994). During the production of low fat meat products, leaner pigs are used as raw material and excess fat is removed in accordance with specifications set out by the manufacturer to satisfy the requirements of the consumer. Simply reducing the fat content may result in products that are more firmer and less juicy. Because proteins will bind water, those that are involved in protein to water interactions will not be available to bind other proteins and as such result in a reduction in protein to protein interactions and therefore a softer product.

2.4.2 Smoking

Smoking, is almost always combined with heat treatment and the following effects, among others, occur as a result of deposition of smoke constituents on the meat products: (1) the imparting of desirable flavour and odour properties; (2) the imparting of antioxidants to the fat and (3) the impregnating of the outer portions of the meat with constituents of smoke which can exert a preservative effect (Pearson & Gillett, 1996).

2.4.3 Cooking

Cooking may be combined with, or carried out directly after smoking of meat. The following are the effects of temperature on the meat (Pearson & Gillett, 1996). These changes occur when heat is applied (± 50 °C), except for the destruction of microorganisms, which may require higher temperatures.

2.4.3.1 Denaturation and coagulation of proteins

Upon cooking the cured meat, the first physical change evident is coagulation on the surface (Pearson & Gillett, 1996). As this occurs, the nitrite reacts with the muscle pigments to produce a stable pink colour. Denaturation and

coagulation involves changes in protein molecules. This is due to the unfolding of the protein or loss of its characteristic conformation, which decrease its solubility.

2.4.3.2 Improvement in palatability

Cooking is the most important factor in improving the palatability of meat products (Pearson & Gillett, 1996). Cooking intensifies the flavour of meat and changes the blood-like or serummy taste of fresh meat to the pronounced cooked flavour and aroma.

2.4.3.3 Destruction of bacteria

Cooking causes the destruction of spoilage organisms. The number and type of organisms destroyed will depend on the time and temperature relationship.

2.4.3.4 Surface drying

Reduction of moisture on the surface of meat as a result of heating, serves several purposes (Pearson & Gillett, 1996). Lowering of surface moisture reduces the water activity on the surface and thus also reduces microbial growth. The reduced surface moisture content plays a key role in preventing not only the growth of surviving bacteria, but also the growth of any other bacteria that may recontaminate the product.

2.4.3.5 Colour stabilization

Cooking has an important function in stabilizing the pink-red pigments formed by the action of nitrite with myoglobin.

2.4.4 Freezing, tempering, forming, slicing and packaging

Smoking and cooking are followed by freezing and tempering. Freezing is mainly done to facilitate slicing and the temperature of the freezer may reach $-20\text{ }^{\circ}\text{C}$ (ARC-ANPI, 1999). Prior to slicing, bacon slabs are held in tempering coolers where internal temperature may be increased to between $-2\text{ }^{\circ}\text{C}$ and $-12\text{ }^{\circ}\text{C}$. This is done to allow bacon to retain its shape when it is subsequently

pressed and to facilitate slicing. Chilled bacon slabs are then pressed. The pressing operation includes placing slabs in a large forming machine which compresses the bacon to a relatively uniform width and thickness. Forming is done to correct the problem of bacon slabs lacking dimensional uniformity to such an extent that slicing yields suffer. After being pressed, bacon slabs are sliced on high speed slicers which automatically shingle slices into selected weight units. This is followed by vacuum packaging.

2.5 THE SENSORY QUALITY OF CURED MEAT PRODUCTS

2.5.1 Colour

The first impression consumers have of any meat product is its colour and this influences buying decisions and affects consumer perception of the freshness of the product (Boles & Pegg, 2001). Fresh meat colour and to an extent cured meat colour both depends on the myoglobin of the meat. Myoglobin is a water soluble protein that stores oxygen for aerobic metabolism in the muscle. It consists of a protein portion and a non-protein porphyrin ring with a central iron atom. The iron atom is an important player in meat colour.

Myoglobin, a purple-red pigment interacts with the nitrite during the curing process to form a pinkish-red pigment which is stabilized upon heating (Kramlich *et al.*, 1973). A series of reactions occur during the curing process (Figure 3) to develop and maintain the desirable pink-red colour of cured meat products.

The pigment nitric oxide myoglobin, is not stable until after cooking, when the final cured pigment nitrosylhemochrome is formed (Boles & Pegg, 2001). The cooked pigment is more stable, but is still sensitive to the presence of oxygen, temperature and light. This is why most cured products are vacuum packaged.

For nitrate to effect a cure, it must first be reduced to nitrite in order to give the meat the characteristic colour of cured meat products (Arnao *et al.*, 1995). The conversion of nitrate to nitrite is accomplished by nitrate reducing organisms in the meat. These microorganisms represent an accumulation of organisms accessing the meat at different stages in the production process by contamination (Johnson, 1994). Most contamination will however be limited to the surface. Further reduction of nitrite in the absence of light and oxygen occurs to obtain the active curing agent nitric oxide which will react with the purplish-red myoglobin in the presence of oxygen to form brown nitric oxide metmyoglobin. The desired pinkish-red nitric oxide myoglobin is formed after reduction of the brown pigment and it is stabilized by heat during cooking.

2.5.2 Flavour and aroma

Nitrite, used as a curing agent, contributes to the development of cured meat flavour (Noel, Briand & Dumont, 1990). Cured meat flavour is complex, but it is believed that as lipid oxidation is prevented during curing, the cured meat flavour intensity is brought forward (Shahidi, 1994). In a study by Jeremiah *et al.* (1996), nitrite was noted to prevent the development of lipid oxidation in cured meat products by reacting with the haem iron in the unoxidized state (ferrous iron) to prevent the formation of the ferric iron which is the oxidized state. Froelich, Gullett & Usborne (1983) reported that the intensity of cured meat flavour increases with the nitrite and salt content. The same authors also noted that during curing, the bacon flavour increased almost linearly with nitrite concentration between 0 and 100 mg/kg. The cured aroma is produced from the reactions of a number of meat constituents with nitrite or nitric oxides, the reaction partners, identified as being alcohols, aldehydes, inosine and compounds containing sulphur (Wirth, 1986).

To some extent the flavour of the smoked product depends on the reaction between the components of the smoke and the functional groups of the meat proteins (Lawrie, 1979). Thus the phenols and polyphenols in the smoke react

with –SH groups of the meat product and carbonyls in the smoke with amino groups in the meat product.

Cooking is normally combined with smoking after curing during the production of cured meat products. Cooking is the most important factor in improving the palatability of meat products (Pearson & Gillett, 1996) and is responsible for the formation of a variety of flavour compounds (Noel *et al.*, 1990). Cooking intensifies the flavour of meat products by changing the 'blood like' taste of the fresh products to the pronounced cooked flavour and aroma. During heating, carbonyl compounds are liberated and Maillard products may be formed; these are responsible for a burned flavour (Van Laack, 1994).

2.5.3 Texture

The major factor that contributes to the texture of meat is its water holding capacity (Lawrie, 1979). When meat is cured, the water holding capacity increases as salt-protein complexes form (Cassens, 1994). The higher the water holding capacity of the cured meat the more tender it will become and *vice versa*. Cooking, which is normally carried out after smoking, reduces the surface moisture of the cured meat products, lowering the water content of the meat products and affecting the texture of the meat products.

CHAPTER 3: OBJECTIVES AND HYPOTHESES

3.1 OBJECTIVES

The objective of this study was to determine the effect of PSE meat on the sensory quality characteristics of low fat bacon. The following specific objectives were formulated:

- To compare the efficiency of curing by determining the percentage brine absorbed, salt concentration and residual nitrite of the final low fat bacon manufactured from PSE and normal pH meat.
- To compare the sensory descriptive attributes of cooked low fat bacon from PSE and normal pH meat as assessed by a trained panel
- To compare, using a paired preference test, consumer buying preferences for packaged PSE and normal pH low fat bacon.
- To compare, using a paired preference test, consumer preferences for the eating quality of cooked PSE and normal pH low fat bacon.
- To correlate the results obtained from the sensory, physical and chemical tests.

3.2 HYPOTHESES

The use of PSE meat for the production of low fat bacon may have a negative influence on the effectiveness of curing (Torley, D'Arcy & Trout, 2000). As a result, colour development, texture and flavour, which form the basis of eating quality (Jeremiah, 1982), may be affected, resulting in a product of lower sensory quality. The following hypotheses were formulated:



- Meat from carcasses with a rapid pH drop (PSE) will have a lower net gain during curing as compared to meat from normal pH carcasses (Fisher *et al.*, 2000). This will directly affect colour development, texture and flavour intensity of both the uncooked and cooked product
- The percentage brine uptake will have a direct relationship with salt concentration (Smith & Lesser, 1982) and the residual nitrite of the final product is expected to follow the same trend.
- The trained sensory panel members will generally describe the low fat bacon from PSE meat as dry and firm with a pale pink colour and this may influence consumer acceptance (Honkavaara, 1988). For low fat bacon from normal pH meat, the panel members will describe the product as juicy, tender and with an intense pink colour. The results will show that there is a significant difference between the two products.
- Results from the consumer test will indicate that consumers prefer low fat bacon from normal pH meat for eating quality as compared to PSE meat. If given the opportunity, they would also prefer to buy low fat bacon from normal pH meat. This is based on a conclusion by (Boles and Pegg, 2001) that consumers can easily discriminate against different colour intensities and that colour is the main single factor that influences purchases.

CHAPTER 4: MATERIALS AND METHODS

4.1 EXPERIMENTAL DESIGN

The conceptual framework for the research is provided in Figure 5. The experiment was designed to include an analytical sensory test, physical and chemical tests as well as consumer sensory tests.

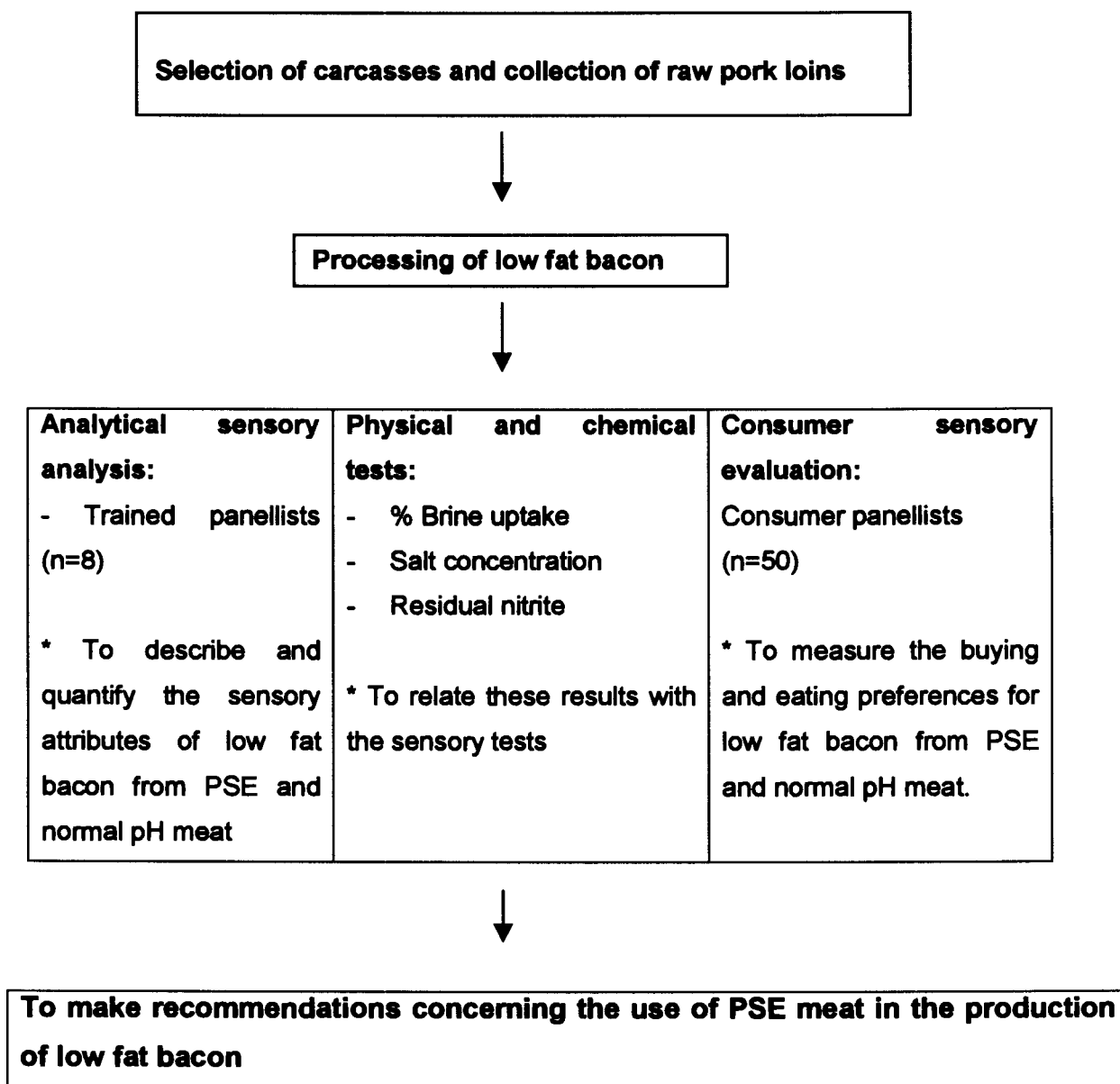


Figure 5: Conceptual framework for the research.

4.2 SELECTION OF CARCASSES

Selection of carcasses for this study was done at Pork Packers abattoir in Olifantsfontein. To get a representation of the carcasses that are normally used, selection was done on different slaughter days. A total of thirty carcasses were selected during a three week period; ten carcasses per day once a week. The carcasses were randomly selected after stunning on the basis of carcass grading (Hennessey grading system) and pH values. To be considered for selection for low fat bacon processing, carcasses had to be marked either "O" grade (13-17 mm backfat thickness) or "P" grade (≤ 12 mm backfat thickness) at the grading station (South African Meat Industry Company, 2000).

The pH of the carcasses was determined at the abattoir's pH station ± 38 minutes after stunning. A Russell pH meter was used to take the pH readings. The pH probe was inserted between the second and the third rib, 45mm from the centerline of the back. The temperature of the carcasses was also recorded at this stage using a hand held checktemp1 thermometer from Hanna Instruments. Carcasses with pH values ≤ 5.9 were regarded as PSE and those ≥ 6 were referred to as normal pH carcasses.

On one slaughter day, selection was done in such a way as to obtain a variation in terms of different grades and different pH values (almost equal ratio). The shoulders of the selected carcasses were marked left and right in order to obtain two loins from each carcass and these two loins were used as replicates. In total, twenty loins were obtained from ten carcasses on each slaughter day. To identify the selected carcasses on the slaughter line, they were tied on each leg with alcohol sterilized coded cable ties. The carcasses were then passed through a freezing tunnel at -24 °C to rapidly bring their temperatures down. This was followed by chilling overnight at 5 °C.

4.3 PROCESSING OF THE CARCASSES

The next day the carcasses were cut (Figure 6) to obtain the two loins that were used for low fat bacon processing. The loins were deboned and external fat trimming was done by hand and care was taken to obtain not more than 10mm fat thickness. The trimmed loins were marked with waterproof labels, covered in plastic bags, packed into crates and transported under chilled conditions to the bacon processing plant, Enterprise Foods in Germiston, \pm 30 kilometres away from the abattoir.

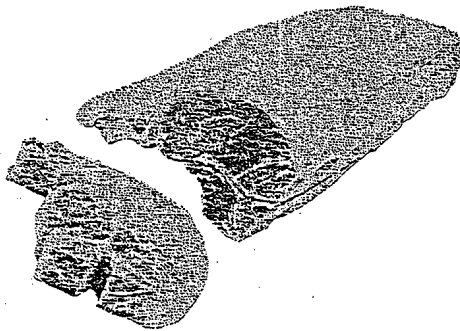


Figure 6: An example of an individual loin (before deboning) used during curing for the production of low fat bacon

At the processing plant in Germiston, the loins were individually weighed and masses recorded. The loins were at this stage ready to be cured. A brine solution was prepared (Table 1) and the loins were individually cured using a Fomaco multiple injection curing machine. The injection machine was calibrated beforehand to pump 13 % by mass for each loin. Immediately after brine injection, the individual weights of the loins were recorded.

Table 1: Percentages of curing ingredients used in the preparation of the brine solution used for the production of low fat bacon.

INGREDIENTS	PERCENTAGE
Salt	12.3
Spices	7.0
Water	79.0
Curing salts	1.7
Total	100

Processing of low fat bacon was carried out as outlined in Table 2. To obtain consistency on different processing days, production controls and quality controls were carried out as specified. To ensure efficiency, quality control was carried out at each step of the process flow. Quality control was used to verify that the steps in the process flow, as detailed in the production control, were carried out correctly.

After brine injection, the loins were hung on a trolley with moving racks, where they were sprayed with a Cold Red Arrow liquid smoke. The time it took for the loins to move through the trolley was ± 4 minutes. The loins were then cooked and this was followed by freezing and tempering, which is done to facilitate slicing. The final products, the low fat bacon packs, were transported

under chilled conditions to the University of Pretoria, where they were frozen at -20 °C until the sensory, physical and chemical tests were carried out.

Table 2: Process flow diagram, including production controls and quality controls to ensure consistency during the production of low fat bacon.

PRODUCTION CONTROL	PROCESS FLOW	QUALITY CONTROL
Fat layer: 10mm	Meat receiving	
Brine temperature: 1-7 °C Meat temperature: 1-3 °C 13 % injection of the brine	Pickle injection	Ensure correct injection percentage and correct temperatures
	Hanging and smoke drenching	
Cook to a core temperature of 37 °C at 55 °C	Cooking	Ensure correct programme is selected on the computer
After cooking, cut strings off and lay flat on trolleys for freezing. Freeze in blast freezer until hard. Freezer temperature:- 26 °C Meat temperature: -12 °C within 48 hours	Freezing	Ensure correct blast freeze temperature at - 26 °C
Move meat after 48 hours to tempering room (-8 °C to -6 °C). Meat temperature before slicing (-4 °C).	Tempering	Ensure correct tempering room temperature at -8 °C.
Slice thickness: 2.5–3.0 mm	Slicing	Ensure meat at -4 °C and not warmer or colder when sliced. Slicing room temperature maximum at 12 °C.
Weigh 250g and pack. Seal and ensure 100 % vacuum. Label. Freeze at -20 °C.	Packaging and freezing	

4.5 SENSORY EVALUATION

4.5.1. Analytical sensory evaluation

4.5.1.1 Descriptive test

Using Generic Descriptive Analysis as described by Einstein (1991), 18 university students were recruited to take part in the descriptive sensory evaluation of low fat bacon. The recruited students attended three screening sessions over two days. The first screening session involved identifying the four basic tastes of sweet, salty, sour and bitter, in solution. During this session, the candidates were also given solutions with different concentrations representing the basic tastes and were asked to rate the intensities of the solutions. The next session involved identifying and rating the intensities of the flavours of meat, smoke and bacon, in solution,. The flavours were supplied by Haarmann & Reimer (S.A.) (Pty) Ltd. This session was repeated. From this initial group, ten students successfully completed the screening session.

Training of the ten member panel took place over a four week period with one session per day. It involved panel discussions centered around the characterization of differences among bacon samples, ballot construction and test sample evaluation. Preliminary sessions involved comparisons between bacon samples available in the market. The discussion centered around what constituted a typical bacon flavour, aroma and texture and to what extent the intensity of these properties varied between samples. The training sessions resulted in 22 mutually agreed on descriptive terms; these were within the attribute groups of aroma, appearance, texture and flavour (Table 3). At that stage, two panel members were excused from the panel as a result of their inconsistency. The number of the final panellists was therefore reduced to eight. During evaluation of the samples, the panellists were provided with score sheets where 10 point numbered category scales (0= not intense; 9=very intense) were used. The scales were anchored at both sides with descriptive attributes.

Table 3: Descriptive terms used for the evaluation of cooked low fat bacon by a trained sensory panel.

Terms	Definitions
Aroma or smell:	Numerous volatile materials detected through the nasal passage and perceived by smelling.
Smoked:	Aromatics associated with smoke for cured products.
Spiced:	Aromatics associated with spices.
Roasted:	Aromatics associated with roasted cured meat products.
Fatty:	Aromatics associated with fatty bacon.
Cured:	Aromatics associated with cured meat products.
Appearance:	Visual presentation of the cooked product.
Brown (muscle):	The intensity of the brown colour associated with the outside of the fried muscle of the low fat bacon.
Compact fibres:	The compactness of the lean fibres. It can either be loose or compact.
Pink:	Overall intensity of the pink colour of the product.
Fat layer:	How thick or thin the back fat is.
Texture:	This is the inner makeup of the product determined through the senses in the muscles of the tongue, jaw or lips.
Juiciness:	Impression of wetness during the first few chews caused by rapid release of muscle fluid.
Chewy:	Chewiness of the meat.
Firmness:	Ease of penetration of the meat by the teeth.
Easily broken:	The ease with which the meat breaks into fragments.
Fatty:	Feeling of fattiness in the mouth while you are chewing.
Flavour:	These are the numerous sensations detected in the mouth and with the nose while eating the bacon.
Spicy:	Intensity of the sensations associated with spices.
Salty:	Saltiness of the bacon.
Fatty:	Intensity of the general fatty flavour.

Table 3: Descriptive terms used for the evaluation of cooked low fat bacon by a trained sensory panel (continued).

Terms	Definitions
Meaty:	Intensity of the cooked meat flavour.
Cured:	Intensity of the very non-specific flavour associated with cured meat products.
Smokey:	Intensity of the smoked flavour.
Porky:	Intensity of the cooked pork meat flavour.
After taste:	Intensity of the aftertaste that remain in the mouth after swallowing.

4.5.1.2 Preparation of samples

Samples were removed from the freezer and stored in the chiller (4 °C) the day before cooking, to thaw. The next morning they were ready to be cooked. Pineware electric non-stick frying pans, were coated with Pick 'n Pay no-name brand sunflower cooking oil, enough to cover the base of the pan (± 22.5 ml). The pan was set to the maximum heat (setting 10) and pre-heated for 75 seconds. Three slices were laid flat on each pan, with no slice on top of the other and enough space was allowed in between the slices. The slices were then fried for ± 1.5 minutes on each side.

Preliminary frying time-temperature combinations were determined, where the trained sensory panel agreed that after ± 1.5 minutes, the rashers were cooked. During a preliminary session, the cooking time was increased to 2 minutes as consumers felt that the rashers were not cooked after ± 1.5 minutes. They were then removed from the frying pan and put in a pre-heated stainless steel bowl. The slices were placed in a pre-heated AEG oven (50 °C) to keep them warm and served within 5-10 minutes. Preparation of samples was carried out in the same way for evaluation by consumers and trained panels.

4.5.1.3 Evaluation of samples

Evaluation of samples took place at the sensory laboratory of the Department of Food Science, University of Pretoria. Low fat bacon from each carcass was assessed twice at different sessions by each panel member. Four samples, 2 representing PSE and 2 representing normal pH low fat bacon were evaluated at each session. The samples, together with forks and an evaluation form (Appendix A) were presented, via the hatches of their individual booths, to panel members to evaluate. The order of sample presentation was randomised to minimise any potential bias due to order effects.

4.5.2 Consumer sensory evaluation

4.5.2.1 Test panel

The consumer test panel comprised 50 students and personnel from the University of Pretoria. Recruitment was carefully done and only individuals that were familiar with, and regularly consumed low fat bacon, were chosen. To be selected to participate, candidates were asked if they consume pork and bacon and how often. The candidates had to be willing to participate in the study.

4.5.2.2 Socio-demographic details of the consumers

Of the total of 50 consumers who participated in this study, 60% were female while 40% were male. The consumers comprised 25% Pedi speakers, 23% Afrikaans speaking and 13% Tswana speaking consumers. The other 29% of consumers were a combination of 8 different home languages, with 7% of consumers not specifying in the questionnaire what their home languages were. Of the total of 40% male consumers, 20% consumed bacon once a week, with 14% consuming bacon less often than once a week and 6% more often than once a week. The female consumers indicated a frequency consumption of bacon once a week (30%), less often than once a week (10%) and more often than once a week (20%).

4.5.2.3 Test location

The consumer test was performed in the sensory laboratory, at the Department of Food Science, University of Pretoria. Individuals were divided into groups and each group was given a specific session time to attend. At least five individuals were handled at a time and each person was allocated to a separate sensory booth. Air conditioning in the testing room was controlled and participants were supervised during the test session. Fluorescent white light was used throughout the testing period and communication between the panellists was not allowed. Two tests, one to determine buying preference and the other to determine eating quality preference, were conducted.

4.5.2.4 Eating quality and buying preference for packaged low fat bacon

In one session, the consumers had to evaluate both the eating quality and the buying preference for low fat bacon samples. A cooler box, designed to imitate a display cabinet, was used for the buying preference test. Two randomly chosen 250g packets of bacon coded with randomly assigned 3-digit code numbers, representing PSE and normal pH low fat bacon, respectively, were clearly displayed flat in the box for consumers to evaluate. For different sessions, different 250g packets were randomly chosen to be evaluated. The selection was done on the basis of pH, as it relates to PSE and normal pH low fat bacon, and not according to fat grading. The consumers were supplied with an evaluation form (Appendix A) to indicate which of the two products they would prefer to buy, if given the opportunity.

For this consumer sensory evaluation, the rashers were cooked for two minutes. Two cooked rasher samples representing PSE and normal pH low fat bacon, respectively, as well as forks, were presented simultaneously in a random order for consumers to evaluate. Samples were coded with randomly assigned 3-digit code numbers. Consumers were presented with an evaluation form (Appendix A) to indicate which of the two products they preferred.

4.6 CHEMICAL AND PHYSICAL ANALYSES

4.6.1 Brine uptake

The loins to be cured were individually weighed before brine injection and their mass recorded as M_1 . The Fomaco brine injection machine was calibrated to pump 13% brine. The mass of each loin after brine injection was recorded as M_2 . Percentage brine pickup was calculated as:

$$\frac{M_2 - M_1}{M_1} \times 100$$

4.6.2 Salt concentration

Salt concentration was determined using the Mohr Method (Egan, Kirk & Sawyer, 1989). Three grams of a homogenised low fat bacon sample was accurately weighed in a porcelain crucible. The sample was fused at 550 °C for 5 hours. The ash was filtered into a volumetric flask and made up to volume. 10 ml was pipetted into a 250 ml Erlenmeyer flask. To this, 3 drops of potassium chromate was added and titrated against 0.05 N silver nitrate until a bright yellow colour changed to a slight brown or orange colour. Salt concentration was calculated as:

$$\% \text{ Salt} = \frac{\text{Titre} \times \text{Normality} \times \text{Factor} (5.844) \times 10}{\text{Sample mass}}$$

4.6.3 Determination of residual sodium nitrite

Residual sodium nitrite was determined using the AOAC method of analysis 973.31 (Horwitz, 2002).

Reagents and apparatus

- (a) *NED reagent*: 0.2 g N- (1- naphthyl) ethylenediamine.2HCl was dissolved in 150 ml 15 % (v/v) CH₃COOH and filtered. This reagent was stored in a glass-stoppered brown glass bottle.
- (b) *Sulfanilamide reagent*: 0.5 g sulfanilamide was dissolved in 150 ml 15 % CH₃COOH (v/v). It was filtered and stored in a glass-stoppered brown glass bottle.
- (c) *Nitrite standard solutions*: Stock solution- 1.000 g NaNO₂ was dissolved in water and diluted to 1l. Intermediate solution- 100 ml of the stock solution was diluted to 1l with water. Working solution- 10 ml of the intermediate solution was dissolved to 1l with water.
- (d) *Filter papers*: Whatmann NO 4 filter papers were used. 3-4 sheets, selected at random, were analyzed for nitrite contamination. Approximately 40 ml water was filtered through each sheet. To this, 4 ml sulfanilamide reagent was added and left to stand for 5 minutes. 4 ml NED reagent was added and mixed. If any sheets were positive after 15 minutes, the entire box was discarded.

Determination

Five grams of a thoroughly comminuted low fat bacon test sample was weighed into a 50 ml beaker and mixed with approximately 40 ml water and heated to 80 °C. A glass rod was used to break up all the lumps and the mixture was transferred to a 500 ml volumetric flask. The beaker and the rod were thoroughly washed with successive portions of hot water, adding all washings to the flask. Enough hot water was added to bring the volume to

approximately 300 ml. The flask was transferred to the steam bath and left to stand for 2 hours, shaking occasionally. The flask was cooled to room temperature and diluted to volume with water, re-mixed and filtered. 2.5 ml sulfanilamide reagent was added to aliquot containing 5-50 μg NaNO_2 in 50 ml volumetric flask and mixed. After 5 minutes, 2.5 ml NED reagent was added, mixed, diluted to volume, re-mixed and left to stand for 15 minutes to develop colour. A portion of the solution was transferred to a photometer cell and Absorbance was determined at 540 nm against a blank of 45 ml water, 2.5 ml sulfanilamide reagent and 2.5 ml NED reagent. Nitrite present was determined by comparison with standard curve prepared as follows: 10, 20, 30 and 40 ml nitrite working solutions were added to 50 ml volumetric flasks and to them, 2.5 ml sulfanilamide reagent added and mixed. The determination was proceeded as above, beginning at "After 5 minutes.....".

4.7 STATISTICAL ANALYSES

All the data was collected in spread sheets using Microsoft Excel 97 and all the statistical analyses were done using Statistica 5.0 (Statsoft. Inc., 1995).

Analysis of variance (ANOVA) was used to analyse the effects of PSE and fat grading on the mean sensory ratings provided by the trained sensory panel for the evaluation of the descriptive attributes of low fat bacon. The mean values for the brine uptake, salt concentration and residual nitrite were also subjected to ANOVA. Interaction effects were also tested and where significant differences were found ($p < 0.05$), the Least Significant Difference (LSD) test was carried out to determine how the samples differed. Correlation analysis using Pearson's product moment correlations were used to correlate the results from the analytical sensory evaluation, physical and chemical tests. The data obtained from the consumer tests were analysed using Roessler's tables (Heymann, 1995).

CHAPTER 5: RESULTS

Although the objective of the research was to determine the effect of PSE pork on the sensory quality characteristics of low fat bacon, it later became clear that carcass fat grading, which formed part of the selection criteria, was also a major important factor. The effect of carcass fat grading on the sensory quality characteristics was therefore also determined.

5.1 THE EFFECT OF PSE PORK AND CARCASS FAT GRADING ON THE SENSORY QUALITY OF COOKED LOW FAT BACON

No significant differences were found for all the sensory attributes ($p > 0.05$) as assessed by a trained sensory panel, when comparing low fat bacon produced from PSE and normal pH pork (Table 4).

A significant difference in the degree of fattiness ($p \leq 0.05$) was found between low fat bacon from O and P grade carcasses. Low fat bacon from O grade carcasses had a significantly larger back fat layer than bacon from P grade. When evaluating the aroma, flavour, texture and the appearance of the product samples, the panel noticed a difference in fattiness. In addition, the attributes of juiciness and ease of breaking were significantly higher in low fat bacon from O grade than bacon from P grade carcasses (Table 5).

When testing for the interaction effect of PSE and fat grading, significant differences ($p \leq 0.05$) were only found for the attributes of after taste intensity and of compactness of the muscle fibres. To determine how the attributes differed when there was an interaction between PSE and carcass fat grading, the data was subjected to a Least Significant Difference (LSD) test (Table 6).

Table 4: Mean ratings (\pm standard deviations) for the descriptive sensory attributes of low fat bacon from PSE and normal pH meat as assessed by a trained sensory panel.

Sensory attributes	PSE (n= 30)	Normal pH (n= 30)	p-value
Aroma¹			
Smoked	6.0 (\pm 0.4)	5.8 (\pm 0.4)	0.28
Spiced	4.3 (\pm 0.3)	4.1 (\pm 0.4)	0.19
Roasted	4.8 (\pm 0.5)	4.9 (\pm 0.5)	0.55
Fatty	4.5 (\pm 0.7)	4.6 (\pm 0.6)	0.44
Cured	5.4 (\pm 1.2)	4.9 (\pm 0.6)	0.08
Appearance²			
Brown muscle	3.6 (\pm 0.8)	3.7 (\pm 0.6)	0.91
Compact	6.1 (\pm 0.4)	5.9 (\pm 0.6)	0.11
Pink	5.2 (\pm 0.7)	5.2 (\pm 0.6)	0.94
Thickness of fat layer	4.6 (\pm 1.3)	4.8 (\pm 1.2)	0.48
Texture²			
Juicy	3.8 (\pm 0.9)	4.2 (\pm 0.9)	0.16
Chewy	5.3 (\pm 0.5)	5.3 (\pm 0.6)	0.90
Firm	5.6 (\pm 0.9)	5.4 (\pm 0.7)	0.33
Easily broken	4.8 (\pm 0.7)	5.2 (\pm 0.5)	0.07
Fatty	4.2 (\pm 0.8)	4.6 (\pm 0.9)	0.09
Flavour¹			
Spicy	4.2 (\pm 0.6)	4.0 (\pm 0.6)	0.46
Salty	5.0 (\pm 1.1)	5.1 (\pm 1.0)	0.84
Fatty	4.3 (\pm 0.9)	4.7 (\pm 0.8)	0.12
Meaty	5.5 (\pm 0.5)	5.6 (\pm 0.3)	0.40
Cured	4.9 (\pm 0.7)	4.8 (\pm 0.4)	0.71
Smokey	5.2 (\pm 0.7)	5.1 (\pm 0.3)	0.76
Porky	4.4 (\pm 0.6)	4.2 (\pm 0.6)	0.16
After taste	4.1 (\pm 0.6)	3.9 (\pm 0.5)	0.90

¹Aroma and Flavour: 0 = Not intense; 9 = Very or Extremely intense

²Texture and Appearance: 0 = Not (attribute); 9 = Very (attribute)

Table 5: Mean ratings (\pm standard deviations) for the descriptive sensory attributes of low fat bacon as influenced by carcass fat grading (P and O grades).

Sensory attributes	P grade ³	O grade ³	p-value
Aroma¹			
Smoked	5.9 (\pm 1.6)	5.9 (\pm 1.5)	0.84
Spiced	4.2 (\pm 1.7)	4.2 (\pm 1.7)	0.58
Roasted	4.9 (\pm 0.6)	4.8 (\pm 1.5)	0.71
Fatty	4.3 (\pm 0.7) ^a	4.8 (\pm 0.6) ^b	0.00
Cured	5.2 (\pm 1.4)	5.1 (\pm 0.5)	0.66
Appearance²			
Brown muscle	3.7 (\pm 0.7)	3.6 (\pm 0.6)	0.33
Compact	6.0 (\pm 0.5)	6.1 (\pm 0.5)	0.38
Pink	5.3 (\pm 0.6)	5.2 (\pm 0.6)	0.81
Thickness of fat layer	4.1 (\pm 1.2) ^a	5.2 (\pm 0.9) ^b	0.00
Texture²			
Juicy	3.6 (\pm 0.9) ^a	4.3 (\pm 0.7) ^b	0.00
Chewy	5.3 (\pm 0.6)	5.4 (\pm 0.4)	0.29
Firm	5.7 (\pm 0.7)	5.4 (\pm 0.8)	0.17
Easily broken	4.8 (\pm 0.7) ^a	5.2 (\pm 0.4) ^b	0.03
Fatty	4.1 (\pm 0.8)	4.8 (\pm 0.8)	0.00
Flavour¹			
Spicy	4.2 (\pm 0.6)	4.1 (\pm 0.6)	0.45
Salty	5.1 (\pm 1.1)	5.1 (\pm 1.0)	0.88
Fatty	4.2 (\pm 0.9) ^a	4.8 (\pm 0.7) ^b	0.00
Meaty	5.5 (\pm 0.5)	5.5 (\pm 0.4)	0.80
Cured	4.8 (\pm 0.7)	4.9 (\pm 0.4)	0.76
Smokey	5.2 (\pm 0.6)	5.1 (\pm 0.6)	0.34
Porky	4.3 (\pm 0.5)	4.4 (\pm 0.6)	0.37
After taste	3.9 (\pm 0.5)	4.1 (\pm 0.6)	0.62

^{a,b}Means in the same row with different superscripts are significantly different ($p \leq 0.05$)

¹Aroma and Flavour: 0 = Not intense; 9 = Very or Extremely intense; ²Texture and Appearance: 0 = Not (attribute); 9 = Very (attribute)

³O grade = 13-17 mm fat thickness; ³P grade = \leq 12 mm fat thickness

Table 6: Mean values (\pm standard deviations) to illustrate the interaction effect of PSE and fat grade on the after taste intensity and the compactness of low fat bacon, as assessed by a trained panel.

	After taste	Compactness
PSE, Grade P	3.89 (\pm 0.51) ^a	6.26 (\pm 0.35) ^b
PSE, Grade O	4.29 (\pm 0.60) ^b	6.11 (\pm 0.41) ^b
Normal pH, Grade P	4.08 (\pm 0.64) ^{a,b}	5.70 (\pm 0.65) ^a
Normal pH, Grade O	3.86 (\pm 0.55) ^a	6.16 (\pm 0.50) ^b

^{a, b}Means in the same column with different superscripts differed significantly ($p \leq 0.05$). Scale: 0 = Not/not intense (attribute); 9 = Very/very intense (attribute)

5.2 THE BRINE UPTAKE OF THE MEAT AND THE SALT CONCENTRATION AND RESIDUAL NITRITE OF LOW FAT BACON

No significant difference was found in the % brine uptake of PSE and normal pH pork (Table 7). There was also no significant difference between the % salt of PSE and normal pH low fat bacon. Saltiness of PSE and normal pH low fat bacon was perceived to be almost at the same level (5.0 and 5.1 %, respectively) during sensory evaluation by a trained panel. Low fat bacon from normal pH meat had a significantly higher ($p \leq 0.05$) residual nitrite content (0.25 ppm) than bacon from PSE meat (0.15 ppm).

Table 7: The mean (\pm standard deviation) % brine uptake of the meat, % salt, residual nitrite and perceived saltiness of low fat bacon as influenced by PSE pork.

	PSE (n=30)	Normal pH (n=30)
% Brine uptake	9.4 (\pm 5.20)	10.7 (\pm 3.60)
% Salt	1.31 (\pm 0.62)	1.30 (\pm 0.61)
<i>Residual nitrite (ppm)</i>	<i>0.15 (\pm 0.17)^a</i>	<i>0.25 (\pm 0.07)^b</i>
Perceived saltiness	5.0 (\pm 1.18)	5.1 (\pm 1.04)

^{a,b}Means in the same row with different superscripts differed significantly ($p \leq 0.05$)

No significant difference was found in the % brine uptake of P and O grade meat. Fat grading did not affect the % salt nor the perceived saltiness.

A significant difference ($p \leq 0.05$) in the residual nitrite content was found between low fat bacon from O and P grade. The residual nitrite content of low fat bacon was significantly higher ($p \leq 0.05$) in O grade than in P grade low fat bacon (Table 8).

Table 8: The mean (\pm standard deviation) % brine uptake of the meat, salt concentration and the residual nitrite of low fat bacon as influenced by carcass fat grading.

	P grade (n=28)	O grade (n=32)
% Brine uptake	9.99 (\pm 3.56)	10.19 (\pm 5.24)
% Salt	1.43 (\pm 0.56)	1.20 (\pm 0.63)
<i>Residual nitrite (ppm)</i>	<i>0.16 (\pm 0.97)^a</i>	<i>0.24 (\pm 0.16)^b</i>
Perceived saltiness	5.1 (\pm 1.08)	5.1 (\pm 1.15)

^{a,b}Means in the same row with different superscripts differed significantly ($p \leq 0.05$)

P grade = \leq 12mm fat thickness; O grade = 13-17mm fat thickness

The interaction between PSE and carcass fat grading resulted in a significant difference ($p \leq 0.05$) in % brine uptake of the meat. These results, were subjected to an LSD test, where it was found that the interaction effect of normal pH meat and P fat grading on the % brine uptake was significantly different ($p \leq 0.05$) to the interactions of PSE and P fat grading; PSE and O fat grading as well as normal pH meat and O fat grading (Table 9).

Table 9: Mean values (\pm standard deviations) to illustrate the interaction effect of PSE and fat grade on % brine uptake of meat for the production of low fat bacon.

	% Brine uptake
PSE, Grade P	8.45 (\pm 2.94) ^a
PSE, Grade O	9.31 (\pm 3.86) ^a
Normal pH, Grade P	13.5 (\pm 3.96) ^b
Normal pH, Grade O	9.71 (\pm 4.38) ^a

^{a, b}Means in the same column with different superscripts differ significantly ($p < 0.05$)

5.3. CORRELATIONS BETWEEN THE ANALYTICAL SENSORY TEST, PHYSICAL AND CHEMICAL TESTS

In normal pH bacon the correlation between % brine uptake and % salt was positive and significant at $r=0.67$ (Figure 6), while at $r= -0.12$ a non-significant correlation was found for PSE bacon samples (Figure 7).

A positive significant correlation was found ($r= 0.62$) between % salt and saltiness in normal pH low fat bacon samples (Figure 9). Again, a non-significant correlation ($r=-0.03$) was found between % salt and perceived saltiness in PSE low fat bacon samples (Figure 8).

There was a non-significant correlation ($r=0.24$) between % brine uptake and residual nitrite in normal pH low fat bacon (Figure 10) and at $r=0.17$, the correlation between % brine uptake and residual nitrite from PSE low fat bacon was also not significant (Figure 11).

5.4 THE INFLUENCE OF PSE PORK ON THE BUYING PREFERENCE AND THE EATING QUALITY OF LOW FAT BACON

Out of the total of 50 consumers, 35 consumers preferred to buy product samples that represented PSE bacon while 15 consumers chose to buy normal pH bacon samples. Evaluating the PSE and normal pH bacon samples, the consumers gave comments about the quality of the samples. From this, it was clear that colour and the size of the fat layer of the product samples seemed to influence choices. Using Roessler's tables, the results showed a significant preference ($p < 0.05$) to buy PSE bacon. The consumers that chose the PSE samples commented negatively on the back fat layer of the normal pH bacon samples, saying it was thick. They therefore chose to buy samples representing PSE bacon.

The reasons given by the 15 consumers who chose to buy samples representing normal pH bacon were also based on the thickness of back fat layer and on colour. These consumers mentioned that colour was the most important factor in deciding which product sample to buy. They considered the colour of the PSE bacon samples to be poor and unacceptable. Although they chose to buy bacon samples from normal pH meat, they remarked that the back fat layer of their chosen samples was thick. They however did not say it was unacceptable.

For eating quality, 27 consumers, from a total of 50 consumers, preferred bacon from PSE meat while 23 consumers preferred bacon from normal pH bacon. No significant preference ($p > 0.05$) was found between the liking of the eating quality of low fat bacon from PSE and normal pH meat.

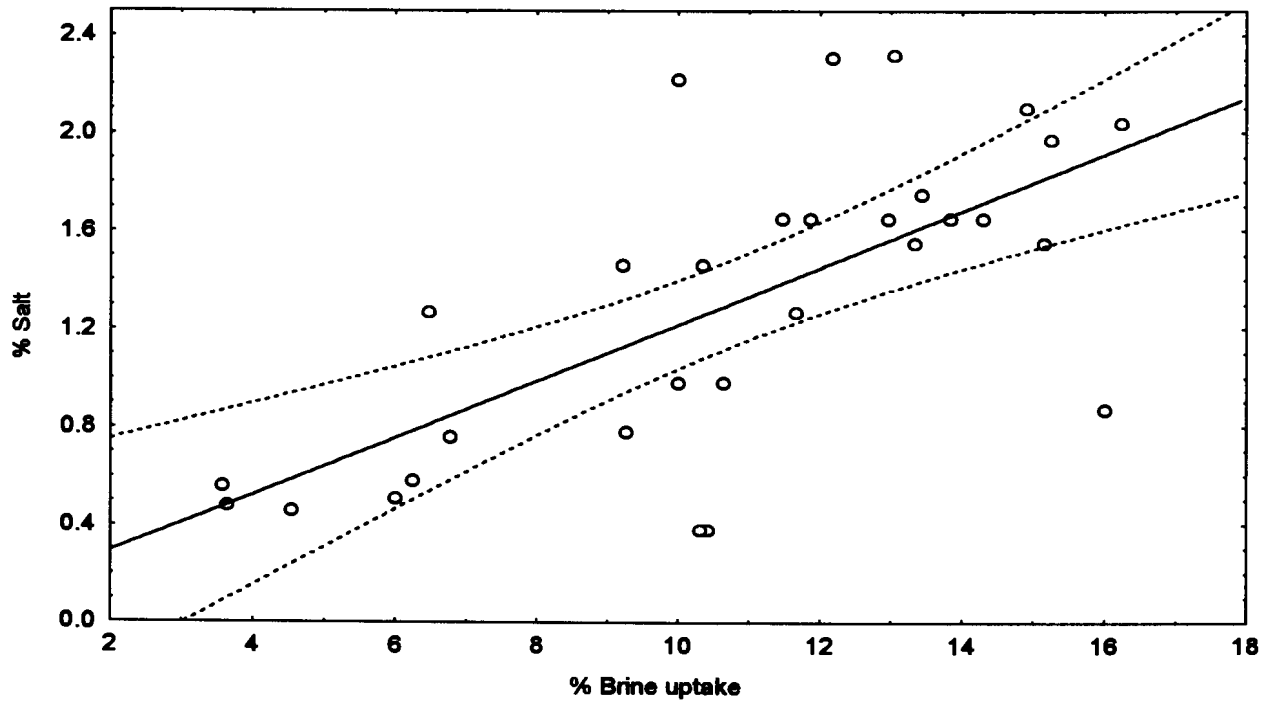


Figure 7: The significant correlation ($r = 0.68$) between % brine uptake of normal pH meat and % salt concentration of normal pH low fat bacon ($n = 30$ loins).

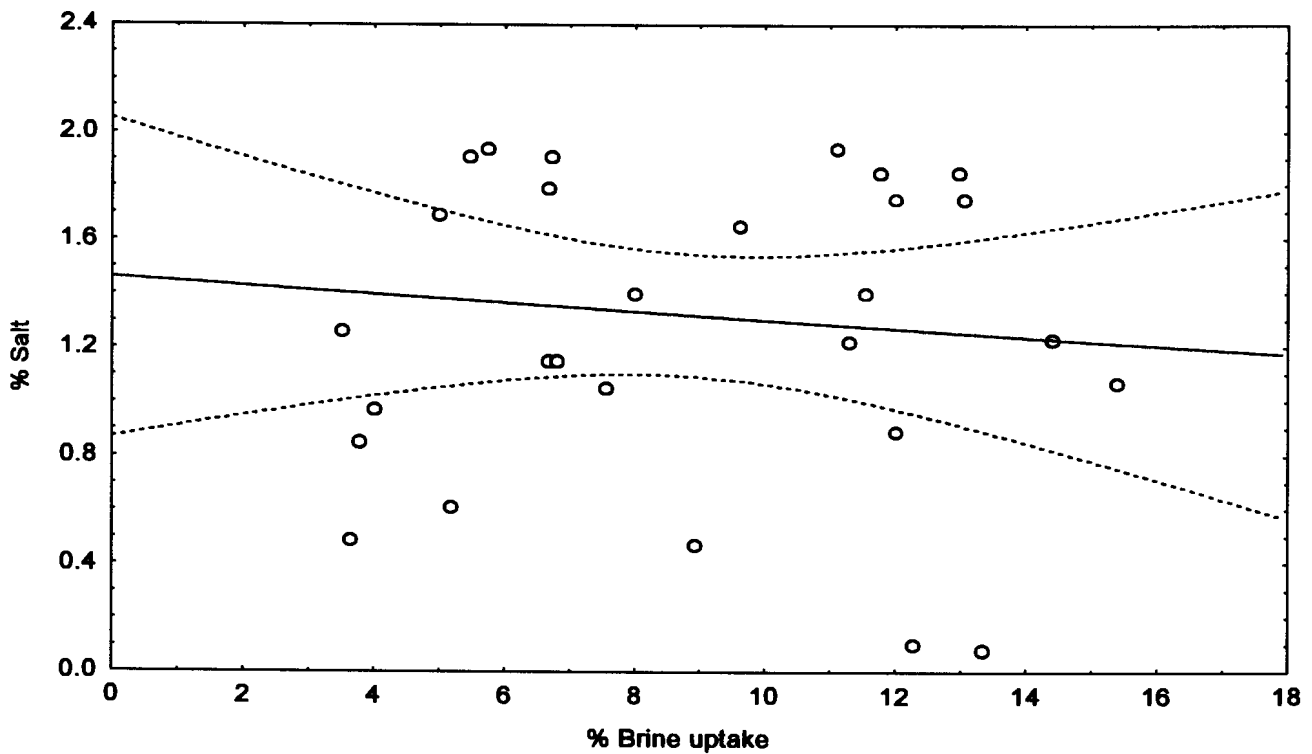


Figure 8: The correlation ($r = -0.12$) between the % brine uptake of PSE meat and % salt concentration of PSE low fat bacon ($n = 30$ loins).

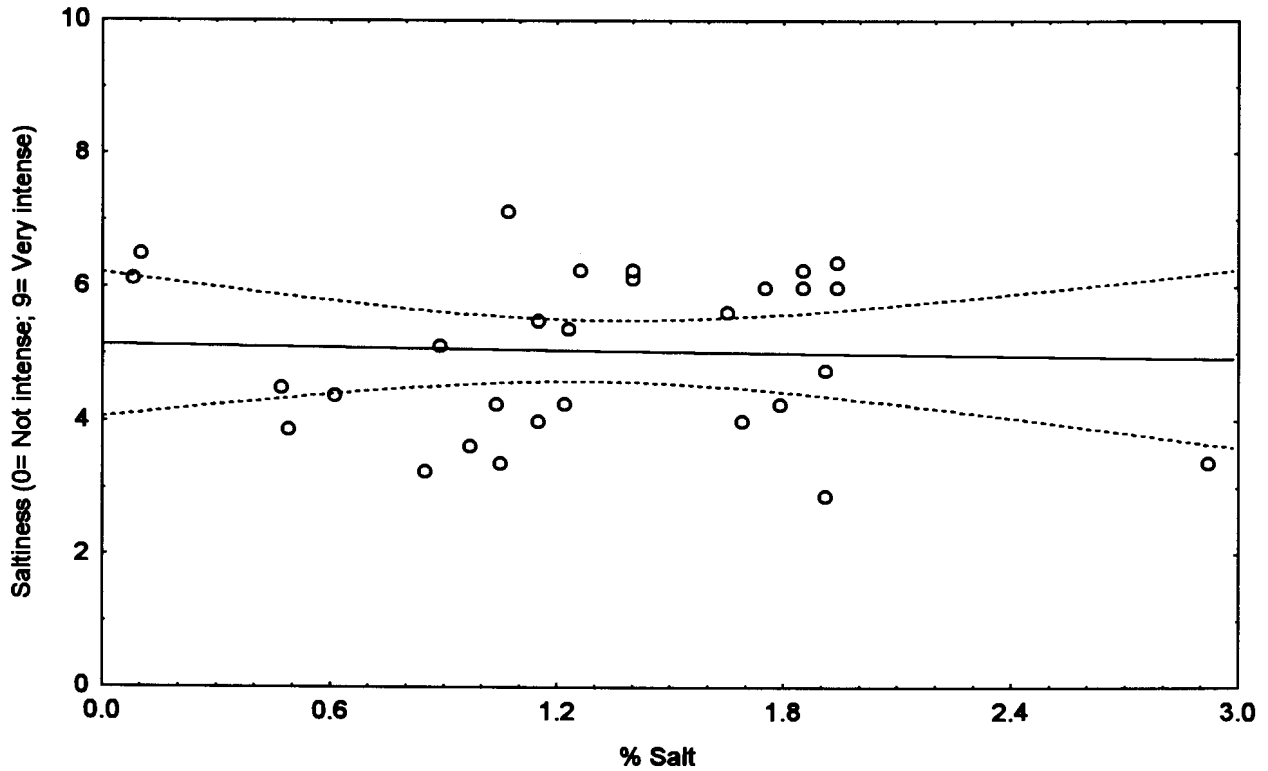


Figure 9: The correlation ($r = 0.03$) between % salt concentration and perceived saltiness of PSE low fat bacon.

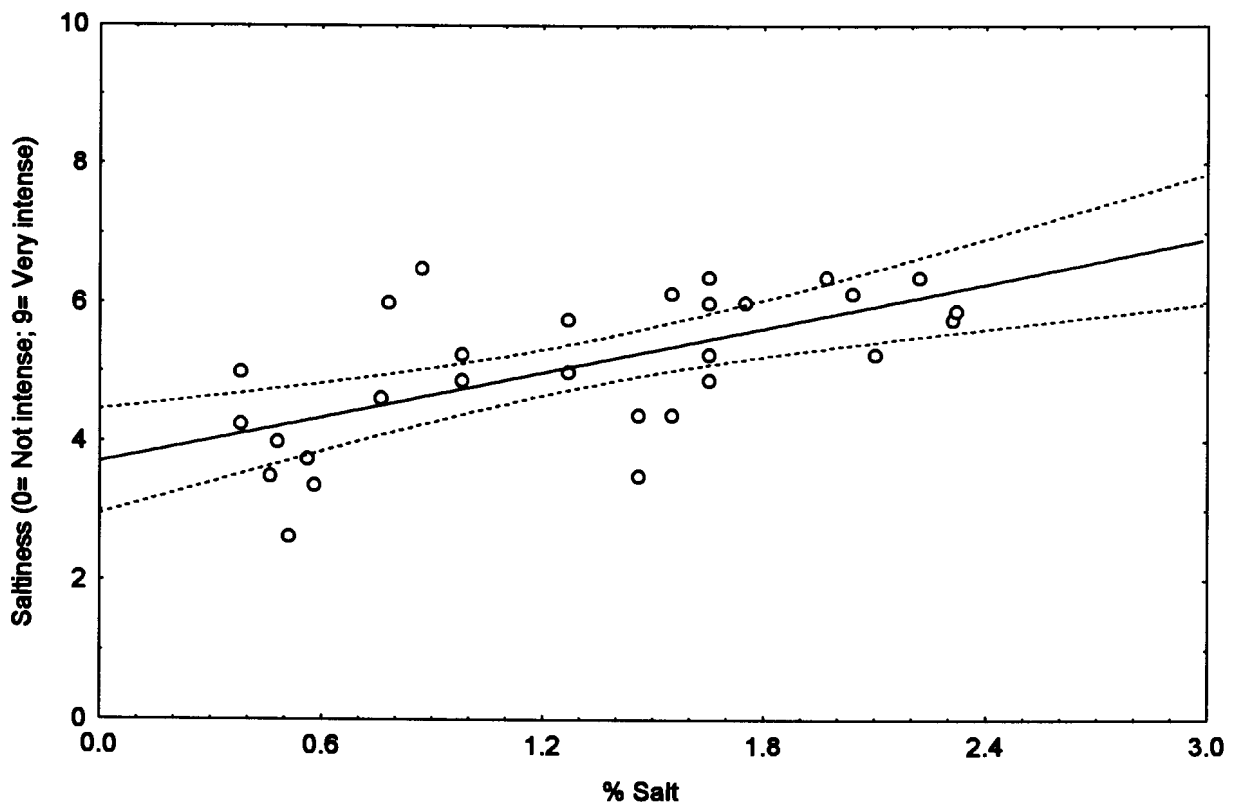


Figure 10: The significant correlation ($r = 0.62$) between % salt and saltiness of normal pH low fat bacon.

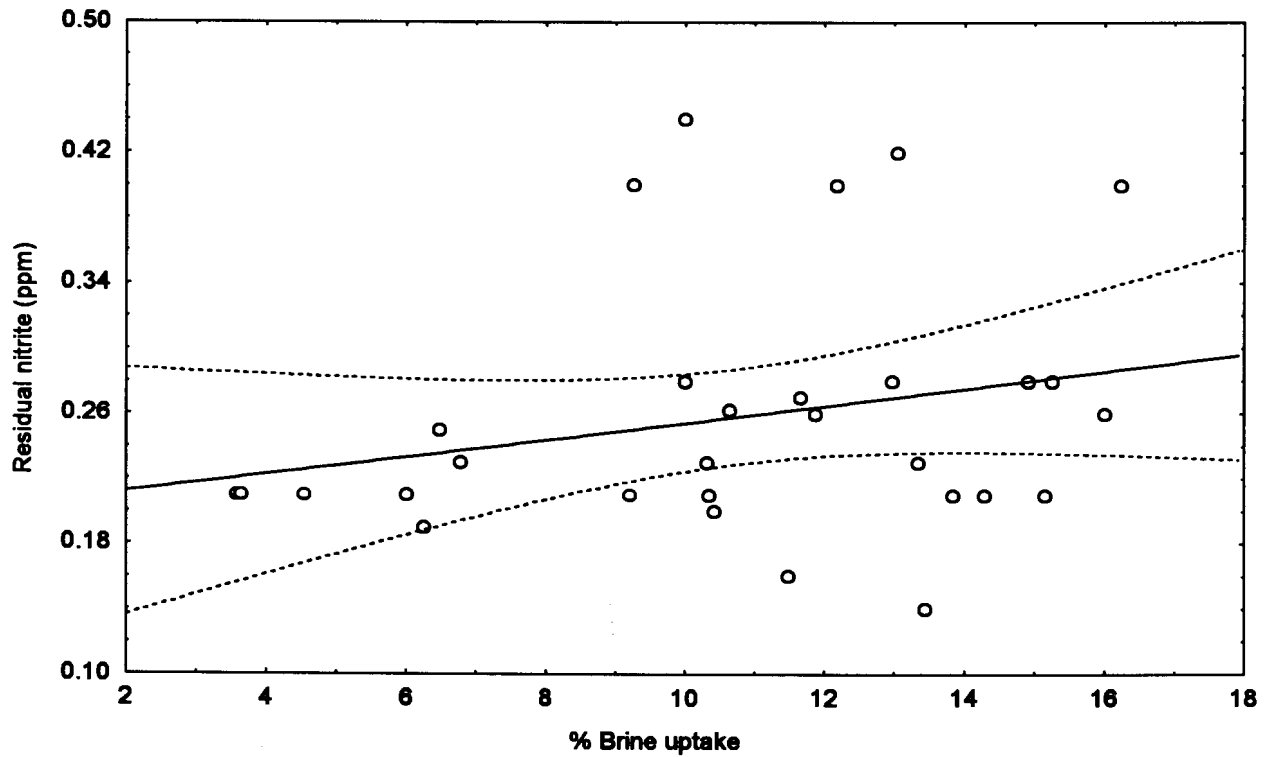


Figure 11: The non-significant correlation ($r= 0.24$) between % brine uptake of normal pH meat and the residual nitrite of normal pH low fat bacon.

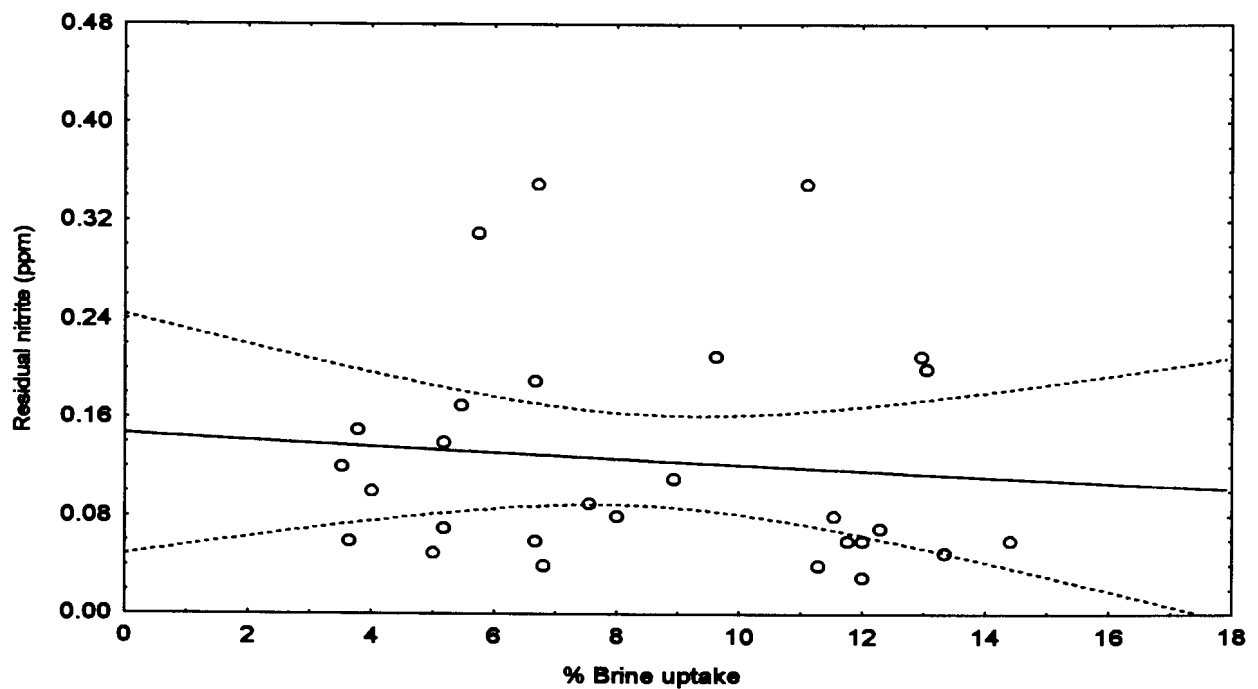


Figure 12: The non-significant correlation ($r= 0.17$) between % brine uptake of PSE meat and the residual nitrite of PSE low fat bacon.

CHAPTER 6: DISCUSSION

6.1 THE EFFECT OF PSE PORK AND CARCASS FAT GRADING ON THE DESCRIPTIVE SENSORY QUALITY OF COOKED LOW FAT BACON

There was no significant difference in the sensory quality of low fat bacon from PSE and normal pH meat. This means that the use of PSE meat did not have any significant negative effect on the sensory quality of low fat bacon, at least after cooking. The consumers also did not indicate a preference for any of the two cooked products. The reason for the absence of differences in the eating quality of low fat bacon from PSE and normal pH meat was probably due to the absence of differences in the amount of brine absorbed during the curing of both PSE and normal pH meat. Noel *et al.* (1990) mentioned that nitrite is responsible for the development of cured meat flavour, while Lawrie (1979) and Boles & Pegg (2001), respectively, emphasised the importance of nitrite in good quality texture and colour development of cured meats.

A significant difference between the carcass fat grades P and O was noticed during the evaluation of aroma, flavour and the thickness of the fat layer around the muscle. Low fat bacon from O grade was found to be fatter than that from P grade. The difference in fattiness was probably caused by the different quantities of fat in the different grades (P grade = ≤ 12 mm fat thickness and O grade = 13-17mm fat thickness), indicating the importance of fat grading in pork and bacon eating quality.

The difference in the thickness of the back fat layer around the muscle was not expected because a specification of fat trimming to within 10mm existed. The difference in the thickness of the back fat layer may have been caused by inconsistency in fat trimming. Fat trimming was done by hand at the abattoir and the person responsible for trimming relied on his estimation that the fat layer was efficiently trimmed. This could have resulted in inconsistency, as some loins were trimmed more than others, resulting in loins of different back

fat thicknesses. The results suggested that loins from the P grade carcasses were trimmed more than those from the O grade carcasses, resulting in thin back fat layers in P grade loins and thicker back fat layers in O grade loins. The problem was further aggravated at the processing plant where consistent back fat layer sizes were not ensured on the different loins before curing. According to the company's specifications, the back fat layer should not exceed 10mm and this must be checked before curing. Since loins from O grade carcasses were more fatter, it is expected that they also exhibited more intramuscular fat. This may have also contributed to the increased fattiness of low fat bacon from O grade meat.

The perceived juiciness of the products was also influenced by carcass fat grading, with low fat bacon from O grade being significantly juicier than that from P grade carcasses. This was expected, since meat from O grade carcasses was fatter than that from P grade. Cross, Berry, & Wells (1980), found that juiciness in meat products is determined by fat levels. Various research results (Giese, 1992; Wirth, 1988) have indicated a direct relationship between fattiness and juiciness.

The results of this study clearly indicate that the low fat bacon flavours had a more intense after taste due to the interaction effect of fat and pH grading. This may be because of the low water holding capacity of PSE meat, facilitating the dissolution of the flavour compounds, especially salt (Arnau *et al.*, 1995), making the flavour compounds more noticeable and resulting in a more lingering effect. These results are supported by those of Barton-Gade, cited by Maw, Fowler, Hamilton & Petchey (2001), who reported that pork flavours were weak in leaner meat.

6.2 THE COMBINED EFFECT OF PSE AND CARCASS FAT GRADING ON THE % BRINE UPTAKE OF THE MEAT AND ON THE SALT CONCENTRATION AND RESIDUAL NITRITE OF LOW FAT BACON

There was no significant difference in % brine uptake between PSE and normal pH meat. This therefore implies that PSE meat does not hinder the efficiency of curing. These results are in contrast with the report by Fisher *et al.* (2000) who stated that PSE meat absorbed less brine compared to normal pH meat.

Salt percentage in the final product was found to be almost similar for PSE and normal pH low fat bacon. The probable reason for this may be the fact that no significant difference was found in the % brine uptake between PSE and normal pH meat after curing, directly affecting the salt concentration. Literature reports conflicting results concerning salt content when PSE and normal pH meat were used for manufacturing meat products. Arnau *et al.* (1995) reported that no difference was found in sodium chloride concentration between Parma PSE hams and Parma normal pH hams. Fisher *et al.* (2000) stated that PSE meat generally absorbed less brine and thus less salt than normal meat, implying that % salt is dependent on the % brine absorbed after curing.

There was no significant difference in saltiness perceived between PSE (5.0) and normal pH (5.1) bacon. This was not surprising since there was no difference in % salt concentration. Froehlich *et al.* (1983) and Coutron-Gambotti, Gandemer, Rousset, Maestrini & Casabianca (1999) reported that salt content affected the perception of saltiness in meat and that the perceived saltiness increased with increasing salt levels. Jeremiah *et al.* (1996) also found the amount of sodium chloride to be positively related to the intensity of the salty aromatics in normal pH bacon.

The significant difference in residual nitrite of low fat bacon from PSE and normal pH meat was not expected since there was no significant difference in the % brine absorbed between PSE and normal pH meat. Residual nitrite is

the amount analytically detectable in cured meat products and it is lower than the amount initially added in the curing brine (Cassens, 1997). It was therefore expected that there would be a direct relationship between % brine uptake and residual nitrite. Although the specific reasons for the differences in the residual nitrite content in PSE and normal pH low fat bacon are unknown, it is suggested that this difference was brought about by the difference in the structure of PSE and normal pH meat.

6.3 CORRELATIONS BETWEEN THE ANALYTICAL SENSORY TEST, PHYSICAL AND CHEMICAL TESTS

The positive significant correlation in normal pH bacon between % brine uptake and % salt confirmed the results of Fisher *et al.* (2000) that the amount of salt is dependent on the % brine uptake. These results also affected the correlations of % salt and perceived saltiness in normal pH low fat bacon, which was also significant. The correlations found with PSE low fat bacon indicated that there was no specific trend between % brine uptake and % salt; % salt and perceived saltiness and between % brine uptake and residual nitrite, as these correlations were not significant. The reason for this is not clear.

6.4 THE INFLUENCE OF PSE ON THE BUYING PREFERENCE AND THE CONSUMER PERCEPTION OF THE EATING QUALITY OF LOW FAT BACON

During the evaluation of low fat bacon for the buying preference, the consumers cited colour and the thickness of the fat layer around the muscle fibre as important deciding factors when purchasing low fat bacon. The consumers who would prefer to buy samples representing PSE bacon mentioned that they were motivated by the perception of the fatness of the product. They stated in their comments that samples representing PSE bacon used in this study had a thin fat layer surrounding the muscle which they

preferred, as compared to samples of normal pH bacon whose fat layer was thick and they would not opt to buy it. Paterson, cited in Pearson & Gillett (1996) mentioned that pigs with a tendency of producing PSE musculature have been found to have thinner back fat. Supporting literature for consumer trends towards purchasing leaner meat products is available (Novakofski, Park, Bechtel & McKeith, 1989; Brewer, Zhu & McKeith, 2001). Giese (1992) reported this worldwide trend by consumers for nutrition reasons and due to anxiety over consuming fatty foods.

The other consumers who chose to buy samples representing normal pH low fat bacon if given the opportunity, cited colour as the main deciding factor for purchasing the product. They stated in their comments that the colour of PSE bacon was poor and unacceptable, which made them to consider buying normal pH bacon. Brewer & McKeith (1999), stated that PSE meat is lighter and that colour is usually indicative of pork quality. These authors concluded that consumers could discriminate among pork of varying colours and that these discriminations influenced acceptability ratings. Although they would prefer to buy normal pH bacon samples, most of the consumers commented on the fat layer of the normal pH bacon saying it was thick. They however did not say it was unacceptable.

For the perception of eating quality, no significant difference was found between the two products. Although fat and colour were the main determinants for buying preference, no comments were given to explain eating quality preferences. It is however believed that colour differences of PSE and normal pH low fat bacon are masked during cooking. These results are supported by those of Flores, Armero, Aristoy & Toldra (1999), who did not find sensory differences with PSE meat compared to normal meat in cooked pork loin.

The other reason for these results could be in a way linked to the way the evaluation form for the consumer test was structured. The evaluation form clearly indicated that the bacon samples to be evaluated were low fat. This could have probably indicated to the consumers that they were to make their

choices based on the fat content. As a result, the fat content may have overridden the issue of PSE colour as the deciding factor for preferences and this could have resulted in most of the consumers making their choice based on fat content.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

The main aim of this study was to determine the effect of PSE meat on the sensory quality characteristics of low fat bacon. This was accomplished by comparing the sensory quality of low fat bacon from PSE and normal pH meat, using a trained sensory panel. A consumer study was also done to compare the buying and the eating quality preferences for PSE and normal pH low fat bacon.

A comparison in brine uptake immediately after curing, between PSE and normal pH meat was determined. This is because curing is mainly responsible for the development of the sensory quality characteristics of low fat bacon. Comparisons were also done on the salt concentration and residual nitrite content of PSE and normal pH low fat bacon.

The results from this study are not supporting the hypothesis that PSE meat has a lower net gain during curing, compared to normal pH meat. As a result of the absence of a difference in % brine uptake of PSE and normal pH meat after curing, no differences were found in the eating quality of low fat bacon from PSE and normal pH meat. The study proves the hypothesis that brine uptake directly affects colour, flavour and texture of the low fat bacon. As no differences were found between % brine uptake of PSE and normal pH meat, no differences were found for colour, flavour and texture of PSE and normal pH low fat bacon, at least after cooking. Although no differences in colour between PSE and normal pH low fat bacon were found after cooking, consumer panel members recognised a colour difference during the evaluation of the buying preferences of the raw packaged samples representing PSE and normal pH low fat bacon. The reason for this colour difference is attributed to the pale musculature of PSE meat, and not to curing. It is concluded that PSE meat does not hinder the efficiency of curing, as there are no significant differences in % brine uptake between PSE and normal pH meat. However, the pale nature of PSE musculature is believed to override the developed pink colour associated

with cured meat products, due to curing salts. This leads to low fat bacon products from PSE meat having a less developed cured colour as compared to products from normal pH meat. This difference in colour is however only visible before cooking. It is recommended that because of the pale nature of PSE meat and because this paleness is not masked by curing, the use of PSE meat for the production of low fat bacon should be avoided as consumers can discriminate against colour and this might influence their choices when making a decision to buy a product.

It was hypothesized that the residual nitrite content of the low fat bacon will have a direct relationship with % brine uptake of the meat. This was however not proven by this study.. There was a significant difference in the residual nitrite content of PSE and normal pH low fat bacon, and although the reasons behind this are not clear, the difference is probably related to the nature of the PSE meat.

The hypothesis that consumers will generally prefer to buy and consume normal pH low fat bacon was based on the pH classification. However, it became apparent during the research that carcass fat grading, which forms part of the company's specification for selection of carcasses for low fat bacon processing, plays a major role as far as the quality of the low fat bacon is concerned. As a result of the different carcass fat grades, there is a variation in the intramuscular and subcutaneous fat, giving rise to significant differences in the appearance, flavour and texture of PSE and normal pH low fat bacon. The consumer panels also indicated a preference for leaner low fat bacon products. It is concluded that for low fat bacon, fat content is an important factor in making the choice to buy a product. It is therefore necessary to produce products with consistent fat content according to specifications. It is recommended that to obtain consistent quality products, only one fat grade must be used for the production of low fat bacon and external fat trimming must be precise and consistent.

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APPENDIX A



The sensory evaluation form used during the evaluation of cooked low fat bacon by a trained panel.

Sensory evaluation of low fat bacon									
SET no. _____					NAME _____				
SAMPLE no. _____					DATE _____				
<p>You are given a sample to evaluate. Evaluate the sample and mark with a cross in the appropriate position.</p> <p>1. Take a few sniffs and rate the intensity of the different aromas of the product sample</p>									
<u>Smoked</u>									
0	1	2	3	4	5	6	7	8	9
Not intense									Extremely intense
<u>Spiced</u>									
0	1	2	3	4	5	6	7	8	9
Not intense									Very intense
<u>Roasted</u>									
0	1	2	3	4	5	6	7	8	9
Not intense									Very intense
<u>Fatty</u>									
0	1	2	3	4	5	6	7	8	9
Not intense									Very intense
<u>Cured</u>									
0	1	2	3	4	5	6	7	8	9
Not intense									Very intense
<p>2. Look at the product and rate the intensity of the appearance attributes</p>									
<u>Brown (muscle)</u>									
0	1	2	3	4	5	6	7	8	9
Not brown									Very brown



The sensory evaluation form used during the evaluation for the buying preference of packaged low fat bacon by consumers.

SENSORY EVALUATION FORM

DATE

SET no

You are presented with 2 samples of low fat bacon. If you were to make a choice of buying one sample, which one would you choose?. Circle the selected sample code.

480

198

Comments: _____

Thank you for your time.



The sensory evaluation form used during the evaluation of the preference for the eating quality of cooked low fat bacon by consumers.

SENSORY EVALUATION FORM

DATE

SET no

You are presented with 2 samples of low fat bacon. Taste from left to right, drinking water in between tasting and circle the code of the sample you prefer.

343

900

Comments:

Thank you for your time.