THE EFFECT OF INTERNAL AND EXTERNAL ROASTING TEMPERATURES ON PORK SENSORY PROPERTIES, PHYSICAL MEASUREMENTS AND CONSUMER LIKING

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ABSTRACT

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The objectives of this research were twofold. Initially it was to quantify the effects of external (roasting) temperature and meat internal (end-point) temperature on the sensory and physical characteristics of selected cuts of pork. Secondly, to investigate Australian consumer preferences to selected cut and cooking condition combinations, and determine the sensory attributes that are most important for preference formation. A two factor central composite rotatable design with independent variables external temperature (120°C-200°C) and internal temperature (65°C-100°C) was used in this trial. A trained sensory panel evaluated the sensory differences of selected cuts (C-loin chop; F-fillet; LE-leg; LO-loin, SH-shoulder, SC-scotch) of cooked pork. Using response surface analysis the effects of these cooking conditions on pork sensory properties (initial and sustained juiciness, pork flavour, hardness, cohesiveness, chewiness) and physical measurements (evaporation loss (%), drip loss (%), cooking time (min/kg), Instron shear force (N), Hunter colour L*, a*, b*) were studied. Sensory attributes initial juiciness (C, F, SC), sustained juiciness (C, F, LE, SC), pork flavour (C, F), hardness (LE, LO, SH), cohesiveness (LE, LO, SH, SC), and chewiness (LO) showed a significant linear relationship with internal temperature. Except for hardness (C) and pork flavour (C, F) all the other sensory attributes showed no significant linear relationships with external temperature. Relationships were also observed between physical measurements and relevant temperatures depending on the cut used. The second stage of consumer evaluation (degree of liking) of selected pork samples was done in Brisbane, Australia and internal preference mapping was used to correlate the trained panel data with consumer data. The results from preference mapping indicated tenderness (hardness) to be the most important sensory attribute driving consumer liking. This segment of Australian consumers primarily liked tender meat that was also flavourful and juicy. Tenderness of pork is achieved at lower internal temperatures for smaller cuts and at higher

internal temperatures for larger cuts. Increasing internal temperature also significantly increases cooking time. Therefore, the recommended internal temperatures for smaller cuts should be within the range 68-70°C and for larger cuts within the range of 80-85°C to optimise the sensory properties in accordance with the liking of this segment of Australian consumers.

The recommended external (ET) and internal (IT) temperatures from this research are: **Chop Roast**- **ET** 160°C-170°C, **IT** 68°C-70°C; **Fillet Roast**- **ET** 160°C-170°C, **IT** 68°C-70°C; **Leg Roast**- **ET** 180°C-190°C, **IT** 80°C-85°C; **Loin Roast**- **ET** 180°C-190°C, **IT** 80°C-85°C; **Shoulder Roast**- **ET** 180°C-190°C, **IT** 80°C-85°C; **Scotch Roast**- **ET**160°C-170°C, **IT** 68°C-70°C.

Acknowledgments

The world of sensory science has always fascinated me. After completing my first degree in nutrition in 1989, further studies in any area was not an option. Living in a developing country meant that finding local institutions which offered courses in specialised areas such as sensory science was virtually impossible. Therefore it has taken me over a decade to fulfill my dream. This work has taken me from "ground zero" to the well established realms of sensory science. The experience I have gained has been well worth it. Not only has my knowledge increased, but I have been enabled to face new challenges and ride the waves of change with the correct attitude. I will always be greatful to my teachers, family and friends who helped me achieve this goal. I wish to take this opportunity to thank some of them by name.

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CHAPTER 1

Introduction

1.1 Background

The future success of the food industry is directly associated with its capability to develop precise knowledge of changing consumer attitudes and perceptions towards food products (Sidel & Stone, 1993), and its ability to understand and fulfill the consumer's needs and expectations in a very competitive market place (Bennett, 1997). The Australian pig industry needs to focus on this process for it to be successful in the future.

Prior to the initiation of the current research, the pork industry had put considerable effort into implementing a quality assurance program. However, this QA program only focused on product safety and consistency that consumers expect, but did not deal with the eating quality attributes of pig meat such as flavour, tenderness and juiciness, which drive consumer preferences. Hence, a study on the feasibility and desirability of implementing an eating quality improvement program (EQIP) for pig meat was commissioned by the Australian pig industry and was conducted by Bennett (1997). The findings of this study were that:

- Australian consumers' attitudes to pork clearly indicated the need to investigate the cooking methods of pork and the effects on its texture and flavour because these consumers considered pork to be tough, dry and poor in flavour. The feedback from supermarket meat managers and retail butchers was also in support of this.
- Only 31 % of the consumers surveyed considered pork to be easy to cook compared to other meats such as beef (54%), lamb (49%), chicken (71%) and fish (51%). These consumers were also unsure of the best cooking method and over-cooked pork as most of them believed that pork had to be very well done to be safe to eat.

There is also no other published information on sensory studies completed on Australian consumers with regard to their assessment of pork eating quality. The phenomenon of over-cooking pork is something that is prevalent in most parts of the world. This is because the majority of consumers have been educated that pork must be well cooked until it is grey or white throughout (Howe et al., 1982).

This research is part of the Eating Quality Improvement Program (EQIP) for pig meat, commissioned by the Australian pig industry through the Pig Research and Development Corporation. A selection of cooking methods (roasting, pan-frying, stir-frying, grilling) and cuts were used with the aim of identifying the optimum cooking conditions for each cooking method and cut combination by means of information obtained from sensory evaluation and physical measurement. The experimental work outlined in this thesis (Chapter 3 and 4) consists of only one cooking method (i.e. roasting).

1.2 Scope

The information obtained from this trial would be of utility value to pork advertising and promotional materials which could encourage Australian consumers to use optimal cooking procedures, and also in the development of simple cooking aids to enable these consumers to easily identify the point of "doneness". This process is expected to increase consumer satisfaction, thereby increasing sales and return which will benefit the Australian pig industry.

1.3 Aims

1. To quantify the effects of external (oven) temperature and meat internal (end-point) temperature on pork sensory and physical characteristics during roasting of portion cuts such as fillet, chop, loin, leg, scotch, and shoulder.
2. To investigate Australian consumer preferences to pork roasts obtained from selected cuts and cooking condition combinations, and determine the sensory attributes that are most important to preference formation.

1.4 Objectives

1. To conduct descriptive sensory evaluation of roasted pork cuts using a trained panel.
2. To establish the effects of internal and external temperatures on sensory attributes and physical measurements for each cut.
3. To conduct consumer preference testing of selected pork samples (sample selection based on descriptive data).
4. To correlate descriptive sensory data with consumer preference data using internal preference mapping to determine sensory attributes driving consumer preferences.

In order to meet these objectives a review of the relevant literature was done (chapter 2) and a group of local residents were screened and trained to evaluate the sensory properties (initial & sustained juiciness, pork flavour, hardness, cohesiveness, chewiness) of roasted pork. Utilising these trained panelists, descriptive sensory evaluation of pork roasted at nine different external and internal temperature combinations (based on a two-factor central composite rotatable design) was conducted and physical parameters (evaporation loss, drip loss, cooking time, Instron Force, Hunter colour L, a*, b*) measured. Response surface analysis was utilised to obtain a clear understanding of these results (chapter 3).

Following this, a group of Australian consumers were recruited for preference testing of selected pork samples. Utilising internal preference mapping, the descriptive sensory data were correlated with the consumer preference data in order to identify sensory attributes driving consumer preferences (chapter 4). Finally, conclusions and recommendations based on the sensory and consumer data are presented (chapter 5).

CHAPTER 2

Eating Quality and Cooking Conditions of Pork

2.1 Introduction

Good quality pig meat as defined by Jul and Zeuthen (1981) is meat that is neither very lean, nor very fat, with a medium uniform pink colour within each muscle. This meat should also be free from any off-odour or off taste, and the texture not tough, stringy, or dry. Sensory properties such as texture, tenderness, juiciness, flavour, odour, and colour are the main attributes of eating quality (Fjelkner-Modig, 1986). Of these attributes colour and some of the odour are sensed before and after cooking and give the consumer with a more long-lasting feeling than the other attributes which are perceived on mastication (Lawrie, 1998). The nutritional aspects and the wholesomeness are other aspects that are considered with the eating quality. Enfalt *et al.* (1997) have found that the overall acceptance of pork was more related to tenderness (r=0.81), than to taste intensity (r=0.67), juiciness (r = 0.67) or off flavour (r=-0.43).

Wood et al. (1979) and Seideman and Durland (1984) have stated that the structure and composition of pork are similar to that of beef. Hence, a reasonable assumption can be made that the textural properties of pork are affected by cooking in a similar way to those of beef.

This chapter initially consists of a brief discussion on the link between eating quality and each of the following: pH, water holding capacity, and intra muscular fat. This is followed by looking at the effects of cooking on the attributes of eating quality, an introduction on cooking methods of meat, and a literature review on the work done with regard to the effects of cooking conditions on sensory properties of pork.

2.2 Eating Quality and pH

Multiple factors such as pH, water holding capacity and intra-muscular fat are dependent on each other in influencing the eating quality of meat. Of these factors the pH in pig meat has received attention, in particular pH measured after chilling the carcass, generally 24 hours (pH_{24}) after slaughter (Jul and Zeuthen, 1981). This is due to the fact that a large spread in pH occurs 45 minutes post-slaughter and pH_{24}. Pale, soft, and exudative (PSE) pork occurs in carcasses with rapid postmortem pH decline (from 7.2 to 5.8 in 45 min) and in carcass with a low ultimate pH (Bendall and Swatland, 1988; Cannon et al., 1995). This condition is a contributing factor to a low water binding capacity, a very pale colour, and stringy and less juicy meat when eaten. Dark firm and dry (DFD) pork results from pre-slaughter stress that reduces glycogen reserves (Dobrenow, 1990). The pH declines in the region of 7.2 to 5.5 to 5.8 within 6 to 8 hours post-slaughter. If the drop of pH stops early because of the lack of muscle glycogen, and the final pH is higher than 6 the carcass is considered DFD (Bendall and Swatland, 1988). DFD meat is dark red-pink with a firm surface free of exudate (Kauffman et al., 1992 as cited in Brewer and McKeith, 1999). It has a high water holding capacity (Jul and Zeuthen, 1981). Normal pork or RFN pork is red firm and non-exudative with a pH greater than 5.8 measured at 2 hours post-slaughter and a pH less than 6 measured at 24 hours post-slaughter (Flores et al., 1999). Variation in pH results in several quality deficiencies. The drip loss in PSE pork is twice as high as normal pork during thawing (Jul and Zeuthen, 1981). Cooking losses of PSE meat is also greater than normal meat. Topel et al. (1976) found cooking losses of 18.31, 15.88 and 14.38% in pale normally coloured and dark loins respectively. Consumers have shown a preference rating of 2:1 for normal pork over PSE or DFD pork (Wachholz et al., 1978), and PSE pork has received significantly lower general appearance scores than normal pork (Fox et al., 1980).

2.3 Eating Quality and Water Holding Capacity

The definition of water holding capacity of meat is the ability of meat to hold fast to its own or added water during the application of forces such as pressing, heating or centrifugation (Hamm, 1960). WHC of meat is linked to taste, tenderness and colour. It affects the appearance of meat before and after cooking and the juiciness during mastication. Reduction of water holding capacity is visible by exudation of fluid known as "weep" in unfrozen meats and 'drip' in thawed meats both uncooked, and as 'shrink' in cooked meats. WHC affects the quality of pork during all processing operations post-slaughter such as storage, aging, grinding, salting, curing, heating, drying, freezing and thawing (Hamm, 1969).

2.4 Eating Quality and Intra Muscular Fat

Intra-muscular fat (IMF) contributes to the eating quality of meat (Saffle and Bratzler, 1959) affecting juiciness, flavour and tenderness (Mottram and Edwards, 1983). Gaddis et al. (1950), have reported that meat with a higher IMF content is juicier than that with a lower IMF. Regression analysis has indicated that sensory juiciness score increased by one point (for grilled chops) with each 0.38 increase in marbling scores (Diamant et al., 1976).

A decrease in tenderness due to a reduction in IMF concentration has been reported by some researchers (Ellis et al., 1990; Warkup et al., 1990). Others (Saffle and Bratzler, 1959; Rhodes, 1970; Davis et al., 1975) have shown only a weak relationship between IMF and tenderness. The prevalence of a threshold value for IMF, instead of a linear relationship between IMF and tenderness has been suggested as the cause of this weak relationship (DeVol et al., 1988). These researchers suggest a threshold value of 2.5%-3% fat. Chops below the fat threshold value have been reported to be significantly tough by DeVol et al. (1988), but varying fat percentages above 2.5 – 3 has shown little effect on tenderness. Wood et al. (1996) have also stated that an intra-muscular lipid (marbling) is one of the factors important in controlling tenderness.

2.5 The Effects of Cooking on Eating Quality

Cooking, especially between temperatures of 55 to 80°C, significantly affects the muscle proteins and thereby the structural properties of meat (Seideman and Durland, 1984). Meat of high quality may be ruined in the cooking and one of poor quality may be very much improved by the method of cooking (Child, 1938). The effects of cooking on eating quality are better understood when discussed with regard to the attributes (tenderness, juiciness, flavour, colour).

2.5.1 Meat Texture and Tenderness

Texture describes a substance's tissue structure. It is the element of a material which is a consequence of a combination of physical properties including its size, shape, nature, composition, and behaviour on deformation or breakdown perceived from senses of touch (kinaesthesis and mouthfeel), sight and hearing (Jowitt, 1974). A comprehensive list of texture descriptions and material properties is well documented by Jellinek (1985). Szczesniak and Kleyn (1963) consider texture as a major attribute of food quality. The texture and juiciness are of absolute importance for the eating value of meat (Tilgner, 1979 as cited in Jellinek, 1985; Harris et al., 1972). Specifically it has been mentioned that consumers do not favour firm, tough, coarse or dry meat texture.

When taking into account all the attributes of eating quality, consumers are willing to compromise flavour and colour for texture and tenderness (Lawrie, 1998). The overall impression of meat tenderness as explained by Weir (1960) consists of three aspects which are the initial ease of penetration of the meat by the teeth, followed by the ease with which the meat breaks into fragments, and finally the amount of residue remaining after chewing. Cooking affects the meat structure by softening the connective tissue proteins due to the conversion of collagen to gelatin, complemented by a toughening of the muscle fibres due to heat coagulation of the myofibrillar proteins (Lawrie, 1966; Pengilly and Harrison, 1966; Visser et al., 1960). The opposing effects of the muscle fibers becoming tough and connective tissues becoming tender is the cause for the heat related changes in meat tenderness (Hamm, 1966; Draudt, 1972).

Toughening of meat due to heat occurs in two phases with the first one evident between temperatures of 40°C to 50°C and the second between 65°C to 70°C (Davey and Gilbert, 1974). The first phase is thought to be due to the denaturation of the contractile system and the second phase is due to the shrinkage of collagen. The increase or decrease of tenderness depends on several factors which include the cooking time and temperature combination (Cover and Hostetler, 1960), and the muscle being considered (Lawrie, 1998). Cooking time is more important for the softening of collagen and the temperature is more critical for the myofibrillar toughening. Thus lengthy cooking time and relatively low temperatures are necessary for meat with a large amount of connective tissues and vice-versa (Weir, 1960). Penfield and Meyer (1975) have reported that the increase in meat tenderness obtained by slow rates of heating meat is caused by other factors including collagen solubility. Paul (1963) has reported that it may be due to collagen becoming more soluble without extensive hardening of the muscle fibres.

2.5.2 Meat Juiciness

Juiciness as explained by Weir (1960) has two organoleptic components. Firstly it is the sensation of wetness that is noticed during the first few chews. This occurs due to the rapid release of meat fluid. This is followed by sustained juiciness, largely due to the stimulatory effect of fat on salivation.

Protein denaturation followed by coagulation of myofibrillar proteins, shrinkage of the myofillaments and a tightening of the microstructure of myofibrils [Cheng, (1976) as cited in Seideman and Durland, (1984)] can increase the amount of " free water " in muscle tissues (Seideman and Durland, 1984). This "free water" increase produces a greater cooking loss (Cheng, 1976) which could contribute to loss of juiciness in the cooked meat. Siemers and Hanning (1953) have mentioned that the extent of shrinkage that occurs during cooking is directly correlated with loss of juiciness to the palate. Meat cooked at low oven temperatures (slowly) has been reported to be more juicy due to less shrinkage (Cover, 1937; Bramblett et al., 1959; Bayne et al., 1969). These researchers have also reported a direct influence of internal temperature on juiciness. In contrary Bramblett and Vail (1964) have reported that meat cooked quickly to a given internal temperature has a lower cooking loss and is more juicy than that which is cooked slowly to the same temperature. The loss in cooking differs somewhat with the cut, the method of cooking and the temperature of cooking (Child, 1938). Cover et al. (1962a,b) and Ritchey and Hostetler (1965) have shown that when the final cooking temperature of beef was increased from 61 to 80°C, a decrease in both, the juiciness and tenderness, occurred.

2.5.3 Meat Flavour

Flavour as mentioned by Meilgaard et al. (1987, page 7) "is the impression perceived via the chemical senses from a product in the mouth. It includes the aromatics which are olfactory sensations caused by volatile substances released from a product in the mouth via the posterior nares, the tastes which are gustatory sensations (salty, sweet, sour, bitter) caused by soluble substances in the mouth and the chemical feeling factors, which stimulate nerve ends in the soft membranes of the buccal and nasal cavities (astringency, spice heat, cooling, bite, metallic flavour, umami taste)".

Application of heat, which produces the reactions involving nitrogenous substances, carbohydrates and fat in meat causes the development of meaty flavour. Evolution of characteristic meat flavours develops at temperatures exceeding 70°C when oxidation of -SH to –SS- groups from actomyosin molecules occur (Hamm and Hofmann, 1965). Landmann and Batzer (1966) report that meat flavour can be considered to have four components that are the non-volatile and volatile fractions of both raw and cooked meat. Some of the heat induced reactions that contribute towards the formation of meat flavour as summarised by Lawrie (1998) include the pyrolysis of peptides and amino acids, the degradation of sugars, the oxidation, dehydration and decarboxylation of lipids, the degradation of thiamin and ribo-nucleotides and interactions involving sugars, amino acids, fats, H_2S and NH_3. Wood (1993) has reported that phospholipids alone are the critical component for full flavour development in meat. Cameron and Enser (1991) have stated that an increase of intramuscular fat in procine *l. dorsi* is associated with improved flavour.

2.5.4 Meat Colour

Visual appearance of both cooked and uncooked meat cuts is one of the important factors used by consumers to judge quality and palatability of meat. The appearance of the meat surface is controlled by the quantity of myoglobin, type of myoglobin molecule, its chemical state and the chemical and physical condition of other components of meat (Lawrie, 1998). The principal pigments of cooked meats is brown globin haemichromogen (Tappel, 1957). Tappel, (1957) has also identified the pink pigment lying adjacent to the brown pigments of partially cooked meat as undenatured oxy-myoglobin

In fresh pork, colour is an indicator of quality and therefore is important for the pork industry (Warner et al., 1993). This is further emphasised by Jeremiah (1982) who has reported that the main factor determining consumer acceptance during the selection of meat purchases is muscle colour. The majority of consumers use colour to determine the degree of doneness of pork, as they believe it to be a measure of safety to eat (Howe et al., 1982). This is an important issue to take into consideration while conducting consumer-related research with cooked pork. The greatest decrease in redness occurs between 50°C and 70°C. Pearson et al. (1962) have stated that the amount of brown colour development in heated pork is related to the level of reducing sugars in the tissues.

2.6 Cooking Methods of Meat

The popular methods used to cook meat include dry heat (roasting, grilling or broiling, pan grilling, pan-frying, and stir-frying), moist heat (braising and cooking in liquid) or microwave heating (microwave cooking). Tender cuts of meat cooked by dry heat methods, result in tender and juicy products (National Live Stock and Meat Board, 1991). Cuts that are less tender are normally cooked for longer periods of time by moist heat methods to soften the connective tissues, to prevent surface drying and to develop flavour.

The rate of heat penetration into meat differs with the cooking method and affects the ultimate tenderness of meat (Cover and Hostetler, 1960).

During roasting, radiant heat of the oven, air, and the pan is conducted and convected throughout the food. Temperatures differ but seldom get much above 260°C. Roasting of meat is sometimes done by using high temperatures at the beginning to sear the outer surface, thereby sealing the juices, then lowering temperature to more evenly distribute the heat throughout the food (Vieira, 1996). This prevents the over cooking of the outer layer before the internal surfaces cook.

Grilling is mostly dependent on infrared radiation. All heat sources used in grilling release visible light and therefore are powerful radiators of infrared energy. Nickel-chrome alloys used in electrical appliances reach temperatures of 1093°C and a gas flame is about 1648°C (Vieira, 1996). The high temperature reduces the time of cooking considerably and is the cause for the development of an intense grill flavour and colour. But, this causes a burned outside and a cold middle in a steak. This is because the rate of moisture evaporation from the surface exceeds the rate of movement of moisture within the product to the surface. During this stage the surface temperature rises from the wet bulb temperature and begins to form a charred surface when the surface temperature exceeds 100°C. Finding the ideal distance from the heat source for grilling is a key factor for producing a rare, medium, or well done steak. Pan grilling is a faster and more convenient method than oven grilling for cooking thinner steaks and chops.

The heating mechanism for pan-frying is mostly conduction and convection. Pan-frying is different from pan grilling because a small amount of fat is added first. The addition of oil brings the uneven surface of the pan into more uniform contact with the heat source. It also lubricates and prevents sticking, and adds flavour to the product. The burned outside and cold middle that happens during broiling can occur in pan-frying.

Stir-frying is similar to pan-frying except that the food is stirred continuously during cooking with high heat. Small or thin pieces of meat are used for this cooking method.

Braising is suitable for less tender cuts. It helps to reduce surface drying in those cuts that need longer cooking. In this method cooking temperatures are usually low. However, heat penetration is faster than in dry heating methods because steam and water conduct heat faster. Meat can also be braised in cooking bags designed specially for the use in ovens. This method reduces the cooking time for larger cuts of meat. Many natural juices and nutrients in foods prepared with moist heat migrate into the cooking medium and can be incorporated into sauces and gravies.

In microwave cooking energy is supplied by short electromagnetic waves. When microwaves are intercepted by dielectric materials such as food, they interact with the dielectric material, giving up energy, which results in a temperature increase of the material. The two main mechanisms by which microwaves produce heat in dielectric materials are ionic polarisation and dipole rotation. Ionic polarisation occurs when ions in solution move in response to an electric field. Ions carry an electric charge and are accelerated by the electric field. Kinetic energy is given up by the field to the ions, which collide with other ions, converting kinetic energy into heat. However this is a less important mechanism than dipole rotation. The dipole rotation heating mechanism is dependent on the existence of polar molecules such as water, a common material present in foods. Under normal conditions, polar molecules are randomly oriented. In the presence of an electric field, the polar molecules line up with the field. As an alternating field is applied, the polarity of the field is varied at the rate of the microwave frequency and the molecules attempt to align themselves with the changing field. Heat is generated as a result of the rotation of the molecules.

In recent times the use of microwave for cooking of meat has increased. Unlike the old microwave ovens the modern ovens with variable power controls allow meat to be cooked more evenly at lower power settings. Though microwave ovens do not brown roasts as readily as conventional ovens a small percentage of the modern ovens have a browning device built into them. Microwave-reheated meat not only retains aroma and flavour, but also has higher acceptability than meat reheated in a conventional oven (National Live

Stock and Meat Board, 1991). There is also a considerable reduction in cooking time and the use of energy.

2.6.1 Broiling, Braising and Roasting

In the past cooking always to a well-done stage has been the recommendation for obtaining the ideal pork roasts (unlike beef and lamb). Various aspects of cooked pork have been studied as early as 1938 (Santorious and Child, 1938; Hardy and Noble, 1945; Noble and Hardy, 1945). The effect of cooking on the sensory attributes of pork has also been the subject of study. However understanding meat cookery is a slow process because of its complex nature caused by size, shape, composition of meat and difficulties involved with measuring thermal properties (Heldman, 1975).

2.6.1.1 Effects of Temperature on Sensory Properties of Pork

Findings of researchers on the effect of temperature on sensory properties of pork are listed in Table 2.1 and 2.2. These results indicate that juiciness was most affected by internal temperatures in comparison to flavour and tenderness. The greater change in juiciness is directly related to water loss caused by the effect of internal temperatures (Heymann et al., 1990; Wood et al., 1995).

Cooked meat flavour is a function of the various tissue components (i.e. muscle fibers and connective tissues) that combine and concentrate as time and temperatures increase (Webb et al., 1961). Published results show no significant changes occurring in flavour for roasts between internal temperatures of 76±1°C and 85°C (Weir et al., 1963; Pengilly and Harrison., 1966; Bramblett et al., 1970; Carlin et al., 1968) even though different cuts (loin, ham, shoulder, leg), cooking equipment and statistical techniques have been used. However the difference in flavour between roasts cooked to internal temperatures 65°C and 85°C has been well established (Webb et al., 1961; Pengilly and Harrison., 1966; Heymann et al., 1990).

Table 2.1 The effect of cooking conditions on sensory properties of pork

Authors	Cooking Conditions/ Cut/ Method	Results / Conclusions
Effect of Internal temperatures on sensory properties of pork		
Webb et al. (1961)	ET (°C): 176.6 IT (°C): 85, 73.9, 65.6, 65.6 held for one hour Cut: loin: Cooking Method: Roasting	Decrease in tenderness ($p<0.05$), and juiciness ($p<0.05$) and an increase in flavour ($p<0.05$) due to an increase in IT.
Weir et al. (1963)	ET (°C): 176.7 IT (°C): 76.6, 85 Cut: loin Cooking Method: Roasting	Decrease in juiciness ($p<0.01$), and an increase in odour scores ($p<0.05$) due to an increase in IT. No significant effect on tenderness and flavour.
Pengilly and Harrison, (1966)	ET (°C): 176.6 IT (°C): 65, 75, 85 Cut: loin Cooking Method: Roasting	Decrease in juiciness ($p<0.05$) and an increase in flavour ($p<0.05$) due to an increase in IT. Tenderness not significantly affected by the end point.
Carlin et al. (1968)	ET (°C): 176.6 IT (°C): 73.8 , 76.6, 79.4, 85 Cut: Ham (Butt & Shank) Cooking Method: Roasting	Higher juiciness for lower IT. Tenderness and flavour not significantly affected.
Bramblett et al. (1970)	ET (°C): 162.7 IT (°C): 76.6, 85 Cuts: Hams and Shoulder Cooking Method : Roasting	Appearance, juiciness and flavour scores similar for all roasts cooked to both the IT. Tenderness scores higher ($p<0.05$) for roasts cooked to 85°C than for those to 76.6°C.
Simmons et al. (1985)	ET (°C): 177 IT (°C): 60, 70, 80 Cuts: Loin chops Cooking Method : Grill and oven	Decrease in tenderness ($p<0.05$) and juiciness ($p<0.05$) with an increase in IT for both cooking methods. Pork flavour intense ($p<0.05$) for only oven prepared chops.
Heymann et al. (1990)	ET (°C): 163 IT (°C): 65.6, 71.1, 76.7, 82.2 Cuts: blade Boston, center loin, 5 rib blade loin, sirloin, boneless center loin, boneless leg Cooking Method : Roasting	Decrease in juiciness ($p<0.05$), metallic flavour ($p<0.05$), and pink colour ($p<0.05$), and an increase in pork flavour ($p<0.05$), and graininess ($p<0.05$) due to an increase in internal temperature. No significant differences in tenderness.

Table 2.2 The effect of cooking conditions on sensory properties of pork continued

Authors	Cooking Conditions/ Cut/ Method	Results / Conclusions
Effect of external temperature on sensory properties of pork		
Weir et al. (1963)	ET (°C): 148.8, 162.7, 176.6, 190.6, 204.4 IT (°C): 85 Cut: loin Cooking Method : Roasting	Initial tenderness ($p<0.01$) influenced by ET. Initial and sustained juiciness unaffected by ET. The flavour and odour scores for roasts cooked at different ET were generally the same.
Jones et al. (1980)	ET (°C): 93, 121, 149, 163 IT (°C): 77 Cut - loin Cooking Method – Roasting	ET 93°C produced roasts significantly ($p<0.05$) less in juiciness. No significant differences in flavour and tenderness due to the effect of the different ET.
Larson et al. (1992)	ET (°C): 82, 93, 121, 163 IT (°C): 74 Cut - leg Cooking Method – Roasting in oven bags	Appearance scores were lower at 163°C compared to 82°C. Juiciness and tenderness scored lower at the 163°C higher temperature than at the two lower temperatures.
Effect of external and internal temperature combination on sensory properties of pork		
Wood et al. (1995)	ET (°C): 170, 180, 190 IT (°C): 65, 72.5, 80 Cut - leg Cooking Method – Roasting	Oven temperature had no effect of eating quality. Juiciness ($p<0.01$-0.001) and abnormal flavour ($p<0.01$-0.001) decreased and pork flavour ($p<0.05$-0.01) increased with the increase in IT.
Zondagh et al. (1986)	ET (°C): 149-232 RSM IT (°C): 77-95 RSM Cut - loin Cooking Method – Roasting	Juiciness was the only pork sensory quality characteristic significantly affected by ET, IT combinations. The lowest juiciness values were found at the highest ET (232°C) at any selected IT. The juiciness values were high below 80°C IT or above 90°C IT.

1- ET- external temperature, IT- internal temperature.

Flavour changes in chops appear to be greater than roasts showing significant differences between 60°C, 70°C, and 80°C (Simmons et al., 1985). This is because of the greater surface browning with the increased surface area in chops as well as in steaks causing greater changes in flavour (Simmons et al., 1985; Wood et al., 1995). The increase in flavour scores as internal temperature increases has been attributed to the taste panel members being conditioned to the flavour of well done pork cooked to an internal temperature of 85°C (Webb et al., 1961). The interactions between indigenous carbonyl-amine compounds to form Maillard reaction products at the higher temperature has also been recognised to contribute to the higher perceived pork flavour of pork roasts during the increase of internal cooking temperature (Bailey, 1983; Mottram, 1992).

The denaturation and shrinkage of endomysial and perimysial collagen sheaths at higher temperatures contribute to loss of water and a decrease in tenderness (Bailey, 1988). This decrease in tenderness due to the increase in internal temperature has been significant according to some reports (Webb et al., 1961; Simmons et al., 1985) but others (Weir et al., 1963; Pengilly and Harrison, 1966; Heymann et al., 1990) show no significant changes.

The use of external temperatures by researchers have been ranging from around 93°C to around 230°C. But the effect of external temperature on sensory properties of pork is unclear. Weir et al. (1963), Jones et al. (1980) and Larson et al. (1992) show a significant effect of external temperatures on sensory properties. In contrary Wood et al. (1995) have shown no significant effects. This may be due to the narrow range of oven temperature used by Wood et al. (1995).

2.6.1.2 Effects of Cooking Conditions on Cooking Losses and Time

Cooking losses are reported as evaporation loss, which includes surface evaporation and moisture lost by exudation followed by evaporation from the cooking pan, and drip loss, which includes the total amount of fat and nitrogenous material remaining in the cooking container. The amount of external fat on the meat prior to cooking influences the quantity of drip loss. An increase in internal temperature increases the cooking losses (Webb et al., 1961; Pengilly and Harrison, 1966; Bowers and Goertz, 1966; Bramblett et al., 1970; Simmons et al., 1985; Hymann et al., 1990; Wood et al., 1995). The increase in cooking losses has been significant (p=0.05) with each 10°C increment (Pengilly and Harrison, 1966) of internal temperature. This increase in cooking losses directly influences a decrease in moisture content and thereby a decrease in juiciness (Haymann et al., 1990) and an increase in graininess (Leander et al., 1980).

Highest cooking losses occur at 93°C (external temperature) as per the results of Jones et al. (1980) when comparing external temperatures (93°C, 121°C, 149°C, 163°C). Contrary to this, Larson et al. (1992) have reported that cooking losses were less for pork roasts cooked at external temperature 82°C and 93°C compared to roasts cooked at 163°C. The different results obtained by both these researchers can be attributed to the use of oven bags by Larson et al. (1992) that could have caused a reduction in the amount of cooking losses.

Similar to cooking losses, cooking time increase due to an increase in internal temperature (Weir et al., 1963; Pengilly and Harrison, 1966; Bramblett et al., 1970; Wood et al., 1995) and a decrease in external temperature (Jones et al., 1980; Zondagh et al., 1986). Below external temperature 207°C the relationship with cooking time is not linear (Zondagh et al., 1986).

2.6.1.3 Effects of Cooking Method & Oven Type on Cooking Losses and Time

Broiling produces greater cooking losses than braising (Weir et al., 1962; Diamant et al., 1976) but require less time (Weir et al., 1962). Various thicknesses of pork chops skillet braised and oven braised have increased in cooking loss and time with increased internal temperatures (Bowers and Goertz, 1966). Adding water in skillet braising has been reported to have little effect on cooking loss or time (Bowers and Goertz, 1966). Comparison of ovens (conventional, forced convection, superheated steam) for roasting pork (Gardes et al., 1995) have shown cooking time reduce considerably using super heated steam ovens. The super heated steam oven produced cooking times 32% shorter than the forced convection and 48% shorter than the conventional oven. Conventional oven produced the lowest cooked product weight.

2.6.1.4 Effect of Chop Thickness on Pork Eating Quality and Acceptability

The thickness of chops is an important factor for achieving optimum textural characteristics during cooking. Very thick pork chops can become overcooked on the outside before the middle has reached the desired degree of doneness. Experiments conducted by Weir et al. (1962) on the effects of thickness on eating quality of pork chops, broiled or braised at 85°C, showed that thickness as a factor in eating quality was more important in broiling chops than in braised chops. However cooking method had little effect on the palatability scores of the thicker chops.

Investigation by Clarke et al. (1983) have indicated that consumers prefer chops between 1.3 and 2.5 cm in thickness. A decrease in tenderness has been shown to be influenced by the thickness and internal temperature interaction (Simmons et al., 1985). In contrary, Wood et al. (1995) have reported no significant effects of steak thickness on any aspect of eating quality. Though the chop thickness for optimum eating quality is yet to be defined Palatability of pork loin chops is improved when (Simmons et al., 1985),

(a) internal temperatures of thick (>1.90 cm) chops is reduced to less than 70°C,
(b) internal temperature of thin (<1.90 cm) chops is reduced to 70°C and,
(c) chop thickness is greater than 1.27 cm.

2.6.1.5 Effects of Cooking Conditions on Consumer Acceptability

A study directed at consumer acceptability of pork chops by Hendrix et al. (1963) as cited in Simmons et al. (1985) showed that 57 % of the chops were less than totally acceptable because of the lack of tenderness and juiciness.

Tenderness of pork has been reported to be the most important quality attribute to consumers (Steenkamp and van Trijp, 1988 as cited in Van Oeckel et al., 1999). This is similar to the finding of Diamant et al. (1976). Enfalt et al. (1997) have shown a strong correlation between the overall acceptance of cooked pork and tenderness (r=0.81).

In order to determine the degree of doneness consumers evaluate the colour of cooked pork, and therefore whether it is safe to eat. Even a slight pinkness may prevent consumers from eating the cooked pork. In experiments conducted by Howe et al. (1982) the panel scores obtained for colour indicated that it is not necessary to cook pork roasts to 80°C or higher in order to eliminate the pinkness associated by consumers with pork that is unsafe to eat.

Comparing the hedonic ratings of two different types consumer groups in Sweden, one 'traditional' and the other 'modern' (according to the Swedish monitor) have shown that the 'modern' group preferred pork cooked to an internal temperature of 68°C, and the 'traditional' group preferred pork cooked to an internal temperature of 80°C (Agerhem and Thornberg, 1993).

Slusar and McDonald (1973) have reported that Canadian consumers prefer the sensory qualities of pork when it is roasted to internal temperature of 85°C rather than 76°C. In contrast a US consumer study to determine the acceptance of pork centre loin roasts showed that consumers preferred roasts cooked to 71.1°C to those roasted to 76.7°C (Siemens et al., 1990). These consumers also preferred roasts with no fat cover more than roasts with 0.6 cm fat cover ($P>0.05$). There was no variation in preference between boneless and bone-in roasts. The preference for lean roast is similar to the consumer survey of Diamant et al. (1976) in which they indicated that least fat was the initial quality cited by majority of respondents.

2.6.2 Microwave Cooking

Microwave cookery is very convenient to consumers because it reduces the cooking and re-heating time considerably. However it is not a traditional cooking method. Bakanowski and Zoller (1984) have reported that the minimum temperature in microwave cooked products was not in the center of the cut, like in conventionally cooked products, but was nearer to the surface.

Cheng and Baldwin (1985) did a comparison of two microwave procedures (using a glass plate or a browning utensil) with traditional stir-fry cooking for pork tenderloin. A 26% energy saving was attained for the microwave heat resistant glass plate method, and the stir-fry method provided a 51% energy saving in comparison to the microwave / browning utensil procedure. Means for flavour, juiciness, colour intensity or colour uniformity of the meat did not differ among cooking methods. Hines et al. (1980) showed that pork loin chops cooked in a microwave oven at a "high" cooking rate were less tender than chops cooked at a "low" rate. Harmon et al. (1990) have reported that chops cooked in M (microwave) and MB (microwave in oven roasting bag) were rated less tender and less desirable by consumers than chops cooked in WB (water bath in an oven roasting bag) and oven roasted.

2.6.3 Frying of Pork

The internal temperature of frying has a distinct effect on the eating quality (Fjelkner-Modig, 1986) causing a decrease both in tenderness and juiciness as a result of its increase. Significant differences were observed for the juiciness parameters between 60 & 68°C ($p<0.01$) and between 68 & 80°C ($p<0.001$) and for the tenderness parameters between 68 & 80°C ($p<0.01$). The internal temperature did not affect the flavour of fried pork. Frying losses increased ($p<0.001$) due to an increase in internal temperature. Samples, which had been fried to an internal temperature of 60°C were pink in the middle and were considered to be raw. Therefore a final temperature of 65-70°C was recommended for frying. Frying chops to a low internal temperature of about 65°C has been reported to be safe for consumption in Denmark because Trichinella spiralis has not been found in slaughtered pigs since 1929 (Bejerholm, 1984). This temperature has also produced optimal juiciness and tenderness.

2.6.4 Cooking in a Bag

Using oven bags for roasting at low oven temperatures of around 82°C and 93°C have reduced cooking losses (Larson et al., 1992). Smith and LeBlanc (1990) used a meat cooker designed to use a lower temperature heat source and conduction heating mechanism. In essence this method consisted of placing the meat in a plastic bag made of clear high density polyethylene and cooking it in an insulated water bath that could be set at temperatures of 65°C to 96°C. Although the water was not in direct contact with the meat, heat transfer between the two was considered to be high since the cooking bag was thin plastic and most of the air was removed from the bag.

The low temperature meat cooker was found to be energy efficient to cook pork chops compared to the conventional pan-frying. However the cooking times for pork chops, was longer ($p<0.01$) with this cooker. The pan-fried pork chops were significantly better liked in appearance than the low temperature cooked chop. Except for the appearance of the pork chops, there were no differences in the sensory scores for texture, flavour, or overall acceptability for pork chops cooked by the different methods.

2.7 Conclusions

It is evident from literature that the quality of pig meat can be improved by controlling important factors such as pH, and intra-muscular fat.

Tenderness, juiciness, flavour and colour of cooked meat are the main attributes of eating quality. The changes in tenderness that occur during cooking are mainly due to the opposing effect of muscle fibres becoming tough and connective tissues becoming tender. A combination of several mouth impressions contributes to the overall perception of tenderness. The juiciness of cooked meat is influenced by the cooking loss, which is correlated with the extent of meat shrinkage. Flavour in cooked meat is produced by the combination of several chemical reactions. Colour is an indicator of quality in fresh meat and an indicator of doneness level in cooked meat.

Identifying optimum cooking conditions depends on several factors such as oven temperature, end-point temperature, cooking method, type of cut, and the amount of different components (e.g. Intra-muscular fat) in the muscle.

Cooking pork at low oven temperatures (93°C and 121°C) have produced superior end products (Larson et al., 1992; Jones et al., 1980) compared to cooking at higher oven temperatures (163°C). However, some research (Weir et al., 1963; Zondagh et al., 1986; Wood et al., 1995) does not mention a distinct advantage in sensory quality when cooking at low oven temperatures. This could be due to the use of a narrow temperature range with the lowest temperature being not less than 145°C in their experimental design.

The review of the available literature on the final end-point temperature has shown that juiciness in pork is most affected, significantly reducing as the final temperature is increased in the range 60-85°C (Webb et al., 1961; Weir et al., 1963; Pengilly and Harrison, 1966; Simmons et al., 1985; Zondagh et al., 1986; Fjelkner-Modig, 1986; Hymann et al., 1990; Wood et al., 1995). Pork tenderness is also significantly reduced according to some reports (Webb et al., 1961; Simmons et al., 1985), but others (Weir et al., 1963; Pengilly and Harrison, 1966; Hymann et al., 1990; Zondagh et al., 1986) have shown no significant effect. Similar to tenderness, there is no conclusive evidence in the effect of flavour. Some studies show a significant increase in pork flavour (Webb et al., 1961; Pengilly and Harrison, 1966; Simmons et al., 1985; Hymann et al., 1990; Wood et al., 1995) and a reduction in abnormal flavour (Hymann et al., 1990; Simmons et al., 1985; Wood et al., 1995) with increasing temperature and others (Weir et al., 1963; Fjelkner-Modig, 1986) show only a small effect on flavour.

Tenderness of pork has been reported to be the most important quality attribute to consumers (Diamant et al., 1976). In comparing two internal temperatures some groups of consumers have preferred the sensory quality of pork cooked to the lower end-point temperature (Agerhem and Thornberg, 1993; Siemens et al., 1990) while others prefer the higher end-point temperature (Agerhem and Thornberg, 1993; Slusar and McDonald, 1973). Unlike other meat such as beef and lamb the colour of cooked pork is a factor that influences the consumers' acceptability. Hence, any future research done on optimising the cooking conditions with the objective of improving sensory quality of pork should take a twin focus concentrating on the product as well as the consumers.

The effects of roasting on sensory and physical properties of pork have been extensively researched in comparison to all the other cooking methods. However, the type of cuts used have been limited to not more than two in most of the these experiments. Furthermore except for Zondagh et al. (1986) and Wood et al. (1995) all the other researchers have restricted either the internal temperature range or the external temperature range when investigating the combined effect of these two temperatures on sensory and physical properties of pork.

The internal temperatures and external temperatures used for roasting pork by previous researchers have been within the range of 60°C-100°C and 90°C-230°C respectively. However only few researchers have used external temperatures below 120°C (Jones et al., 1980; Larson et al., 1992) and above 200°C (Weir et al., 1963; Zondagh et al., 1986) for roasting pork.

This literature review suggests an internal temperature range of 60°C-100°C and an external temperature range of 120°C-200°C for studying the effects of roasting on sensory and physical properties of different pork cuts.

CHAPTER 3

Roasting Conditions on Sensory and Physical Characteristics of Different Cuts of Pork

3.1 Introduction

Eating quality is, for consumers, one of the most important properties of pig meat (Jul and Zeuthen, 1981) which determines their liking and preference and influences their purchasing decisions (Chambers et al., 1993).

The experimental work that is explained in this chapter is part of the eating quality assurance program investigating the optimisation of cooking procedures for pork. The objective of this trial was to quantify the effects of external (oven) temperature and meat internal (end-point) temperature on pork sensory and physical characteristics during roasting of portion cuts such as fillet, chop, loin, leg, scotch, and shoulder.

3.2 Experimental Design

3.2.1 Response Surface Methodology

An experimental optimisation approach known as Response Surface Methodology (RSM) was used for this experiment. It is regarded as a popular optimisation technique in food science, because of its thorough theory, relatively high efficiency and simplicity (Arteaga et al., 1994).

The treatment structure is basically a designed regression analysis (Giovanni, 1983). Unlike factorial treatment structures, where the purpose is to determine if and how the factors influence the response, the objective of an RSM experiment is to forecast the values of a response variable (called the dependent variable) based on the controlled values of the experimental factors (called independent variables). According to Box et al. (1978), RSM is aimed at specifically identifying effects of independent variables and seeking conditions which optimise the response in question.

Several classes of treatment structures can be used as RSM experiments. A central composite rotatable treatment structure, which is a class of second-order RSM experiments, was used in this trial. Second order models are better able to fit complex relationships between the dependent variable and the independent variables and can also be used to locate the predicted maximum or minimum values of a response in terms of the levels of independent variables (Meilgaard et al., 1999).

A rotatable design is one that has equal predictability in all directions from the centre. The central composite rotatable design for two independent variables contains a minimum of (2^N+$2N$+1) points, or experiments, where N is the number of independent variables. The experiment defined by these points consists of 2^N for a full factorial design, $2N$ 'axial' or 'star' points at each axis at distance from the center equal to the distance to each vertex (maximum and minimum values), plus one or more points at the center of the design.

Normal RSM coding for a two-factor design was used for this experiment assigning values of -1.414 and 1.414 for the lower and upper limits. The central coordinate was assigned a value of 0 [(lower limit + upper limit)/2)]. Figure 3.1 represents the central composite rotatable design used in this experiment.

The analysis is carried out by fitting a mathematical function to the experimental data (sample means), usually by least squares regression analysis. Normally, a linear or quadratic function is inferred to be sufficient. The model obtained is statistically tested to evaluate the validity. These tests include a lack-of-fit using replicated points and residual analysis. Finally, the statistically valid model is used to predict the optimum of the system.

3.2.2 Roasting Trial Design

A two factor Central Composite Rotatable Design (Zondagh et al., 1986) was chosen for the roasting trial. The independent variables were external (oven) temperatures (ET) and internal temperatures (IT) as shown in Figure 3.1.

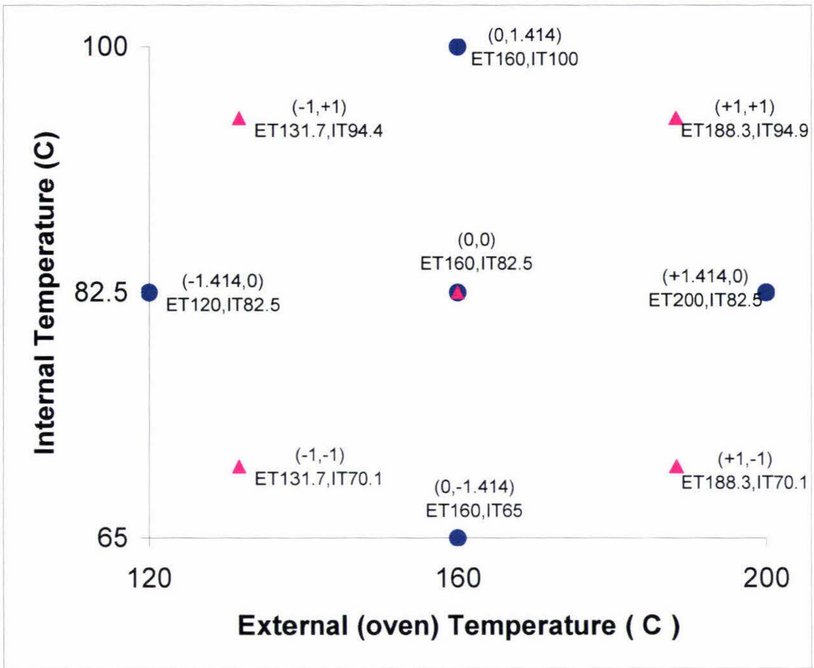


Figure 3.1 Central composite design

In the graph (▲) represents experiments from the 2^N full factorial design (four for two factors known as corner points) and (●) indicates the $2N$ star points and the centre point. The red labels indicate the nine cooking conditions used.

The ET range used in this trial was between 120°C - 200°C. This range was established after a detailed examination of the literature. Though some researchers have used lower (Jones et al., 1980; Larson et al., 1992) and higher (Weir et al., 1963; Zondagh et al., 1986) ET, special consideration was given to selecting the external temperatures that consumers normally used at home. The selected IT range was 65°C – 100°C. This selection was based on the nature of the cooked meat. At internal temperatures below 65°C, the meat is considerably pink and can exude a large amount of blood. Although this can be masked to a large extent by using the red light during sensory evaluation, focus groups conducted by

Saunders et al. (1998) have indicated that Australian consumers do not like pork meat with such characteristics. Hence considering temperatures below 65°C was not appropriate. The upper limit of internal temperature, 100°C, was selected for two reasons. At 100°C internal temperatures plateau as water evaporates and reaching a higher internal temperature would be difficult. Over cooking of pork has been prevalent among Australian consumers (Stollznow et al., 1997; Saunders et al., 1998) and therefore it was considered important to investigate the eating quality of pork cooked to a high internal temperature.

As indicated in Figure 3.1 the corner points and the star points were grouped separately. The centre point was included in both groups to give a total of five cooking conditions per group. One of this group was replicated to give a total of fifteen combinations for each cut. As a result of the focus group conducted by Saunders et al. (1998) six cuts were used for this roasting trial. The names of the cuts, replication details and average fresh weight are given in Table 3.1.

Table 3.1 The names of the cuts, replication and average fresh weight

Cut	Muscle Tested[1]	Replicated set	Average fresh weight[2] (kg)
Fillet (whole)	Psoas major	Corner points	0.385 (0.305-0.506)
Leg roasts (bone-in, minus rump and hock)	Gluteobiceps	Corner points	6.548 (4.808-8.272)
Loin chops (skin off, fat on)	Longissimus thoracis et lumborum	Corner points	0.270 (0.224-0.308)
Loin roasts (half loin, bone-out, rolled)	Longissimus thoracis et lumborum	Star points	3.865 (3.299-4.977)
Shoulder roast (bone-out, rolled)	Supraspinatus	Corner points	4.010 (2.991-4.731)
Scotch roasts (bone-out, rolled)	Serratus ventrallis	Star points	1.656 (1.224-2.162)

[1] Largest muscle in each cut; [2] Range in brackets

Assessing too many samples would cause sensory fatigue that may degrade the performance of a panelist (Greenhoff & MacFie, 1994). Due to this reason and limits in the cooking facility the panelists tasted five samples obtained from five different cuts per day according to a randomised design. The scotch roasts were tested in one group after the other five cuts.

3.2.3 Sensory Evaluation

Descriptive sensory analyses are the most advanced tools used by the sensory scientist (Lawless and Haymann, 1998) and is useful in obtaining a detailed specification of the sensory attributes of a single product or a comparison among several products (Gillette, 1984). Human subjects are used in this method as a measurement tool to provide a sensory description of products by evaluating the intensity of a series of sensory attributes. According to Sidel and Stone (1985) sensory skills vary from person to person and most individuals do not know what their ability is to smell, taste, or feel a product. All individuals do not also qualify for all tests. Hence it is imperative that a selection process needs to be implemented when starting a descriptive analysis program. The selection, training and testing for this trial was conducted in the Sensory Evaluation Facility, Institute of Food, Nutrition and Human Health located at the Turitea Campus of Massey University.

3.2.3.1 Sensory Panel Selection and Training

An advertisement was placed in the local newspaper asking for people to participate in a sensory panel on pork. One hundred and eight people responded. Fifty people were selected from this group based on age (18-52 years) and location (Palmerston North City) of residence. A product attitude survey form (Appendix 3.1) was sent to all the fifty candidates. The completed survey forms were assessed giving consideration to each candidate's availability, interest and general health. Thirty-three candidates were selected from this stage and were invited to a screening session that was conducted over three days.

The screening program consisted of a combination of tests such as basic taste recognition, triangle and ranking tests. To be in agreement with the rule that the screening programs need to be product specific (Basker, 1988) and due to the unavailability of the experimental products and equipment at this selection stage a ranking test for sausage hardness was included. 20 panelists qualified to undergo further training for this project. The group consisted of 3 males and 17 females, who ate pork regularly, aged between 18 and 52. None of these panelists had previous experience in meat sensory evaluation.

Panel training is necessary to expose the panelists to a common set of experiences (Duizer 1992). The main objective is to obtain "a set of instruments", all of whom respond alike (Powers, 1984). In order to achieve this, the panelists were trained so that they

(a) became acquainted with the test procedure
(b) improved their individual ability to recognise and identify sensory attributes
(c) improved their individual sensitivity to and memory for test attributes, so that their sensory judgement would be accurate and consistent.
(d) individual sensory judgements matched the overall panel judgements.

Ten training sessions lasting one and half-hours per session were conducted. On the first day, the panelists were briefed on the protocols (Appendix 3.2) to follow during tasting of meat samples. This was followed by group discussions to identify the attributes to be tested and to define the end descriptors and reference standards. When deciding on the terms to describe the sensory attributes of products Civille and Lawless (1986) have mentioned many characteristics that need to be taken into consideration. All terms identified by the panel were listed and those that were discriminative, non-redundant, that linked to consumer acceptance or rejections, and related to instrumental and physical measurements were selected with the direction of panel leader.

The panelists were trained to evaluate six sensory attributes in cooked pork. They were initial juiciness, cohesiveness, hardness, pork flavour, sustained juiciness and chewiness, definitions of which are given in Table 3.2.

A 10cm unstructured line scale was used, with appropriate end descriptors for each attribute (Hovenier et al., 1993). The reference standards identified by the panel for each attribute were anchored on the scale (Appendix 3.3). These reference standards were available during all the sessions so that the panelists could calibrate their scores accordingly. Finally, refinement of the score sheet, reference standards, and definitions, continued until the panelists were satisfied with the score sheet and best sequence, and everyone understood each term completely. Refer to Appendix 3.2 for the detailed training programme.

Table 3.2 Definitions of the attributes and their references

Attribute	Definition
Initial Juiciness (first squash)	The perceived amount of juice released during the first squash. 6.5 – Celery ; 10- Apple
Hardness (first chew)	Force required to bite completely through sample placed between molars. 1- Philadelphia cream cheese ; 5.5 – Spanish olives with pimento ; 8.5 – pepperoni
Cohesiveness (first chew)	The amount that stays together after the first bite. 0.5-Rice wafers; 5.5 – Jelly beans; 9 – Soft jubes
Pork Flavour (After 7th chew)	Perceived pork flavour 8- Pork cube(Roast Fillet I.Temp-65°C)
Sustained Juiciness (Just before swallowing)	The perceived increase or decrease in juiciness released during the entire chewing process. 1.5- Tuna ; 6.5 – Carrots
Chewiness (Just before swallowing)	Number of chews (in comparison with the references) that are needed to prepare the sample for swallowing, chewing with a constant rate and uniform force. Cheese- 2 ; Jelly beans- 6.5 ; Salami- 8

The performances of the individual panelists, as well as the panel as a whole, were monitored during the last four sessions of training. Sets of five samples were served during each session. Three samples were from the same cut of meat cooked at different internal temperatures and the other two samples were replicates from another cut of meat. The data was analysed statistically by means of analysis of variance to look for judge, replicate and sample effects. Results from these sets of samples enabled us to determine if panelists picked up smaller differences in the attributes and displayed consistency in their replicated responses. The individual scores of each panelist were compared with the average panel scores to identify any outliers. All results were discussed with the individuals and further training and motivation were provided as required.

3.3 Sample Preparation – Sensory Method

3.3.1 Meat Selection

The pork cuts for this trial were obtained from Australia (Pacific Meat Packers Pty Ltd.). These cuts were obtained from this meat processor to ensure that it would be representative of pork available to the Australian consumers. The cuts were obtained from carcasses weighing around 70 to 75 kilograms. The average intra-muscular fat level was around the 2% level across all cuts. The following characteristics, which are known to affect sensory properties, were not found in any cuts: pale, soft and watery, dark and dry appearance (Heymann et al., 1990).

3.3.2 Meat Packing and Storage

Except for the fillets and loin chops all the other cuts were vacuum packed individually. The fillets were vacuum packed in packs of two and the loin chop (uniform in thickness) in packs of six. The cartons were blast frozen and then held for two days to completely equilibrate to -20°C before shipping. The temperature was monitored during the transport and no significant rise was observed. On arrival of the consignment at Massey University the meat was immediately loaded into a -30°C freezer.

3.3.3 Meat Cooking

Two convection ovens (Bistro, Electrolux AR85 Auto-reverse) were used in this trial. Initial calibrations of these ovens were done by placing eight thermocouples throughout the cooking chamber and monitoring temperatures over the full range of dial settings. It was identified that the dial settings were accurate to within 2°C. However, a thermocouple was placed in the center of the chamber during each cooking run to monitor the correct air temperature. The performance of both ovens was identical.

Five samples were tested each day. The meat from the different cuts were randomly selected, removed from frozen storage and thawed in a chiller at 4°C. The leg, loin and shoulder roasts were thawed for 72 hours, the scotch roasts were thawed for 48 hours and the loin chops and fillets were thawed for 24 hours. Just before the start of cooking pH of the cuts were measured using a digital pH meter (Sentron® 2001 pH). Further details of this measurement are mentioned in the instrumental evaluation section.

The cuts were placed on separate oven racks over a drip tray. Thermocouples (Type T, Homersham T30-2-506) were inserted into the geometric center of the cut and starting temperatures noted. The trays were then randomly placed in the preheated ovens and cooked to the specified internal temperature. When the samples reached the required internal temperature, they were removed from the oven and cooking losses and cooking times were recorded. These recordings were done immediately for fillets and chops but for the remaining larger cuts a ten minutes standing period was applied (National Live Stock and Meat Board. 1991).

3.3.4 Preparation of Cooked Samples

After cooking the required muscles (Table 3.1) were removed from the cuts and wrapped in aluminium foil and placed in a 60°C incubator (Conthern Incubator with a range of 0 - 75°C) until further preparation for sensory evaluation. A portion of meat was also taken for the objective measurement and placed in a plastic bag and stored at 4°C. A Minolta colour meter was used to obtain Hunter L*a*b* colour parameters of the cut surface of cooked meat, taking three readings at different points on each surface. Further details are outlined under instrumental evaluation section.

Before serving the cooked meat wrapped in foil was removed from the incubator and the outer surface of the meat removed. It was then cut into cubes using the following set protocols;

- All meat samples were obtained from the geometrical centre of the excised muscle.
- All samples were of uniform size (1 cm cubes) to the closest approximation.
- The samples were cut so that the muscle fibers were parallel or perpendicular to the surface of the sample.

Two cubes were placed in a plastic pottle (120ml, 4PCD, Carter Holt Packaging) that had been labeled with randomised three digit codes, the pottles lidded and returned to the incubator for at least 10 minutes before serving to maintain an equilibrium of sample temperature. To prevent heat loss, Styrofoam wells were used during testing of the samples. The samples were placed in these wells according to an order that balanced the 'order of presentation' and 'first order carry-over' effects (MacFie et al., 1989). The panelists evaluated the samples in the presented order cleansing their palates with a piece of plain water cracker and filtered water between each sample.

3.4 Instrumental Evaluation Methods

3.4.1 Temperature Measurement

As previously mentioned the type T thermocouples, supplied by Homershams (T30-2-506) were used. These thermocouples were calibrated in ice water and boiling water prior to use. A custom made data station, containing a Pentium® 166 PC and running an Intellution software was used.

The number of thermocouples used to monitor the internal temperature varied depending on the size of the cut. Three thermocouples were inserted into each leg, loin, shoulder and scotch roasts, two into each loin chops and two into each of the fillets. Cooking was stopped when the lowest reading thermocouple reached the required internal temperature. All data were then transferred into Excel 97 for analysis.

3.4.2 pH Measurements

The pH values of the uncooked meat were measured using a Sentron® pH meter with solid-state, spear-tip electrode (temperature compensating). Calibration was done in pH 7.00 and pH 4.00 buffers. Three measurements were made at different points on each of the large cuts, two measurements on each of the fillets, and one measurement on each of the chops.

3.4.3 Colour Measurements

Cooked samples taken for objective testing were removed from the chiller after two hours and a fresh surface was cut across the piece of meat. A Minolta Colour Meter was used to obtain Hunter L*, a*, b* colour parameters of the cut surface. L* refers to lightness of meat (0= black, 100= white), a* refers to redness and goes from green which is negative to red which is positive, the extreme colours of b* are yellow (positive) and blue (negative; MacDougall, 1986 cited in Hovenier et al., 1993). Three readings were taken at different points of the surface. Calibration of the colour meter was done each day using the supplied white calibration tile.

3.4.4 Texture Measurement

Instrumental measurement of textural properties has become a common practice in the food industry. Often the objective is to establish which sensory property can be accurately predicted by instruments, and thereby improve on line quality assurance (Macfie and Hedderley, 1993). Warner-Bratzler shear force (WBSF) is often used as a measure for meat tenderness (Boccard et al., 1981).

Sampling methods determines the relative contributions of the two structural components (muscle fibre & connective tissue) of meat when subjected to the application of a force between teeth of a taste panelist or the instrumental shearing device (Poste et al., 1993). Some researchers (Bouton et al., 1975; Murray & Martin, 1980) have stated that magnitude of the correlation coefficient of the sensory and instrumental results is dependent of the method of sample presentation. The American Meat Science Association (AMSA, 1978) accepts both parallel and perpendicular core sampling methods.

The samples used for colour measurement which was stored at 4°C were removed from the chiller 20 hours after cooking and placed in the air-conditioned texture testing room for two hours for the temperature to equilibrate to 20°C. A cork borer was used to cut six 12 mm diameter cores from each sample taken parallel to the muscle. Visible fat, connective tissues and other non-uniformities were avoided. The cores were then sheared across their mid-regions and the maximum force and total energy of shearing recorded.

Shear Force (N) was measured perpendicular to the muscle fibre (Haymann et al., 1990), using a Warner-Bratzler shear rig (blade aperture of 60°) attached to an Instron Universal Testing Machine (model. 1405) with a one kN load cell, and a cross head speed of 100 mm min^{-1} (van Oeckel et al., 1999).

3.5 Data Analysis

3.5.1 Trained Panel Data

All the results were entered in Excel 97 as shown in Table 3.3 and imported into Genstat (Genstat 5 Committee., 1993) for statistical analysis.

Table.3.3 The form of data for REML

Judge Name	Session	Cut	Cook Code			Attribute $x_1 \dots x_6$			
				X_1	X_2	X_3	X_4	X_5	X_6
1...15		1...6	1...9						

Investigation of Outliers

As a consequence of the training of the panel it is usual to assume that all assessors are scoring the attributes in a similar pattern, but no training can eliminate all variation in usage (Arnold and Williams, 1986). Examples of variation include:-

1. Panelists differ in the overall level of scores they give.
2. Panelists vary in sensitivity to certain attributes.
3. Panelists vary in their range of scoring.

Therefore this variation needs to be investigated before further analysis. During sensory profiling if an assessor scores N samples for V attributes the results can be displayed as a N*V matrix where each row refers to a particular sample and each column to a particular attribute. Basically the N*V matrix represents a configuration of N points, one for each units, in V dimensions. When M assessors participate in the evaluation, giving a set of M such matrices, a Generalised Procrustes Analysis compares them in pairs, keeping the residual sums-of-squares, and performs a principal coordinate analysis of the residual sums-of-squares to obtain an ordination representing the individual configurations. The rows of the matrices must represent the same set of units, in the same order; however there is no need for them to have the same number of columns (although generally they will do). The resulting coordinates for the assessors are then examined by plotting the first two dimensions, and obvious outliers or different groupings of assessors discovered.

Generalised Procrustes Analysis rotates each matrix in turn to the average of the previous matrices (the ‘consensus’). Once a consensus based on all the matrices has been derived, it performs a Principal Component Analysis on the consensus. As a check for assessor differences, the sums of squared differences between pairs of rotated matrices can be analysed using Principal Co-ordinate Analysis (Arnold and Williams, 1986) to identify panelists or groups of panelists with very different scoring patters. In this trial Procrustes Analysis was completed for each of the fifteen sessions and all sessions compared to identify if any outlying individuals or groupings of assessors existed. Overall there were no consistent pattern of outlying individuals or grouping of assessors observed (over the fifteen sessions). Results of this analysis have not been included since there is no direct relevance to the objective of this thesis. However some of the plots are added in the Appendix 3.4.

Different judges were present at different sessions. Hence, the next step was to estimate and remove the judge effects to obtain mean values for each cut under each cooking condition (Cook Code) which were not distorted by the specific panelists at a given session. This was done by fitting a linear model (Constant + Judge + Cut * Cook Code) using the GENSTAT REML (Residual Maximum Likelihood/Restricted Maximum Likelihood) procedure (Genstat 5 Committee (1993)).

The means that were obtained from the REML analysis data were tested for statistical significance using Tukey's Multiple Comparison method at 95.0% simultaneous confidence intervals.

The raw sensory data for each sample were also analysed using MINITAB to generate associated regression equations. The following quadratic polynomial regression equation (model) was assumed for evaluating the individual Y-attributes:

$$\ddot{Y} = \alpha + \beta_1 ET + \beta_2 IT + \beta_{11}\, ET \times ET + \beta_{22}\, IT \times IT + \beta_{12} ET \times IT$$

Where $\ddot{Y}$ = the predicted Y – attribute's value; ET = external temperature, °C; IT = internal temperature, °C; β- estimated coefficients

The data were first analysed using this model. From the results all terms except the main terms, that were not significant were eliminated from the model and reanalysed. The level of significance used for the response surface analysis was preset at $P<0.09$.

The means that were obtained from the REML analysis were saved in the form as indicated in Table 3.4 for each cut.

Table.3.4 The form of data for PCA per cut

Cook Code	Means of Attribute $x_1 \ldots x_6$					
1...9	X_1	X_2	X_3	X_4	X_5	X_6

This data matrix was submitted for Principal Component Analysis (Genstat 5 Committee (1993)).

Principal component analysis (PCA) is a multivariate technique that is used to describe interrelationships among multiple dependent variables (sensory attributes) and among objects (samples) (Joliffe, 1986). In sensory evaluation the input to PCA is comprised of attribute ratings describing a set of products. Some use the mean ratings as the input data and others use the raw data obtained from each panelist (Kohli and Leuthesser, 1993). Due to the rotating sensory panel the average scores were used in this analysis. PCA transforms the original set of dependent variables combining correlated attributes into new variables (Principal Components) (Johnson and Wichern, 1992).

The principal components are obtained through a linear combination of the dependent variables that maximises the variance within the sample set. The first principal component accounts for the maximum possible amount of variance among the sample. The remaining principal components account for, in sequence smaller amounts of the total variance in the data set and are not correlated with preceding components. This is similar to finding a new set of axes in space to replace the *N*-dimensional space of the original data set with a smaller set of axes or dimensions. The maximum number of components that can be formed in a data set is equal to the number of the dependent variables used in the analysis. However, the first few Principal Components may account for most of the variation in the data, thus simplifying display and interpretation.

The loading of the attributes and the scores of the samples from two principal components are plotted against each other as two-dimensional plots. The factor loadings are used to understand the dimensions and the scores illustrate the similarities and differences among the products. Samples that are further apart in the map are perceptually more different than samples found together (Coxon, 1982).

In this trial for each cut, the mean attributes for each cooking condition were analysed using Principal Component Analysis (PCA), to examine the interrelationship among the attributes. PCA can be performed with either the matrix of correlations between the attributes, or the variance-covariance matrix of the attributes; in this case the covariance matrix was used because all the attributes were measured utilising the same scale.

Data obtained during the cooking process such as drip loss, evaporation loss and cooking time per kilogram, and rheological data from the Instron measurements were then correlated with the first and second principal components and added to the plots. This technique has been used by Beilken et al. (1991).

3.6 Results and Discussion

The external temperatures (ET) and internal temperatures (IT) associated with the nine different cooking conditions, which represent the different pork samples, are detailed in Table 3.5.

Table 3.5 Cook code and corresponding external and internal temperatures

Sample	Cooking Condition[1]	ET (°C)	IT (°C)
1	$(E^{120}I^{82})$	120	82.5
2	$(E^{131}I^{94})$	131.7	94.9
3	$(E^{131}I^{70})$	131.7	70.1
4	$(E^{160}I^{100})$	160	100
5	$(E^{160}I^{82})$	160	82.5
6	$(E^{160}I^{65})$	160	65.0
7	$(E^{188}I^{94})$	188.3	94.9
8	$(E^{188}I^{70})$	188.3	70.1
9	$(E^{200}I^{82})$	200	82.5

[1] E-external temperature°C; I-Internal Temperature°C

3.6.1 Chops

3.6.1.1 Results

The means of sensory and physical measurements for chops that were obtained from the REML analysis were tested for statistical significance using Tukey's Multiple Comparison method at 95.0% simultaneous confidence intervals. The mean scores (sensory & physical measurements) and Tukey's scores are listed in Appendix 3.5. These results indicate significant differences in the following:

Sensory measurements
Initial juiciness, sustained juiciness, and pork flavour

Physical measurements
Drip loss, evaporation loss, cooking time, Hunter colour L*, Instron shear force

A. Response Surface Analysis

To obtain an understanding of the complexity of ET and IT in influencing these differences the quadratic model coefficients (Table 3.6) need to be examined.

Analysis of variance show that a decrease in internal temperature significantly influences an increase in initial juiciness (P=0.002), sustained juiciness (P<0.001) and pork flavour (P<0.001). The effect of external temperature on these attributes is not significant. An increase in hardness is slightly (P=0.070) influenced by the decrease in external temperature. However the variation accounted for by the model is low. P-values for pork flavour (P=0.045) show moderately significant influence of external temperature on this attribute.

The response surface shows that maximum evaporation loss (%) occurs at the highest Internal (100°C) and external (200°C) temperature combination. Hence a better yield can be obtained at only low ET-IT combinations.

Table 3.6 Q. Regression model coefficients for pork chops for substitution into equation[1].

	IJUICE		HARD		COHESIVE		FLAVOUR		SJUICE		CHEW	
	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P
A	2.22112	0.000	5.59773	0.000		NS	4.75449	0.000	3.95547	0.000		NS
ET	0.00127	0.903	-0.00941	0.070		NS	-0.00975	0.045	-0.00371	0.351		NS
IT	-0.09239	0.002	0.01540	0.179		NS	-0.05458	0.000	-0.05504	0.000		NS
ET*ET	E	NS	E	NS		NS	E	NS	E	NS		NS
IT*IT	E	NS	E	NS		NS	E	NS	E	NS		NS
ET*IT	E	NS	E	NS		NS	E	NS	E	NS		NS
R-Sq	56.7%		43.3%				74.5%		77.2%			
Lack of fit (P)	0.868		0.810				0.420		0.854			
	EVAPORATION LOSS		DRIP LOSS		COOKING TIME		COLOUR L*		COLOUR a*		COLOUR b*	
	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P
A	19.3280	0.000	9.30600	0.000	15.0110	0.000		NS		NS	9.93145	0.000
ET	0.1993	0.000	-0.09725	0.000	-0.0508	0.057		NS		NS	-0.0117	0.045
IT	0.4803	0.000	0.09702	0.048	0.4160	0.000		NS		NS	0.0237	0.069
ET*ET	E	NS	E	NS	E	NS		NS		NS	-0.0003	0.348
IT*IT	E	NS	E	NS	0.0148	0.032		NS		NS	0.0045	0.006
ET*IT	.0069	0.096	-0.00470	0.030	E	NS		NS		NS	-0.0010	0.082
R-Sq	84.7%		77.1%		86.2%						71.5%	
Lack of fit (P)	0.448		0.723		0.664						0.884	
	MAXIMUM FORCE											
		NS										
A		NS										
ET		NS										
IT		NS										
ET*ET		NS										
IT*IT		NS										
ET*IT		NS										
R-Sq												
Lack of fit (P)												

A-Constant
ET-External Temperature °C
IT-Internal Temperature °C
NS- Not Significant
E - Eliminated

[1] $\ddot{Y} = \alpha + \beta_1 IT + \beta_2 ET + \beta_{11} IT*IT + \beta_{22} ET*ET + \beta_{12} IT*ET$

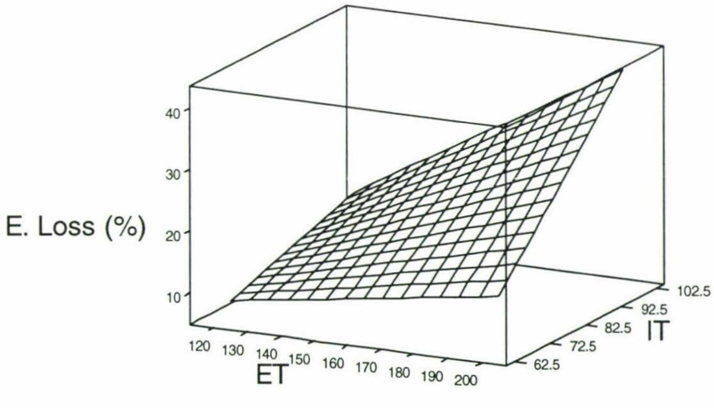


Figure 3.2 Response surface of evaporation loss (%) for chops

The effect of external temperature on drip loss is highly significant (P<0.001) compared to the effect of internal temperature which is moderately significant (P=0.048). There is also an indication of an influence of ET-IT combination (P=0.030). This indicates that the effect of different internal temperature on drip loss is high at lower external temperature compared to higher external temperature (Figure 3.3).

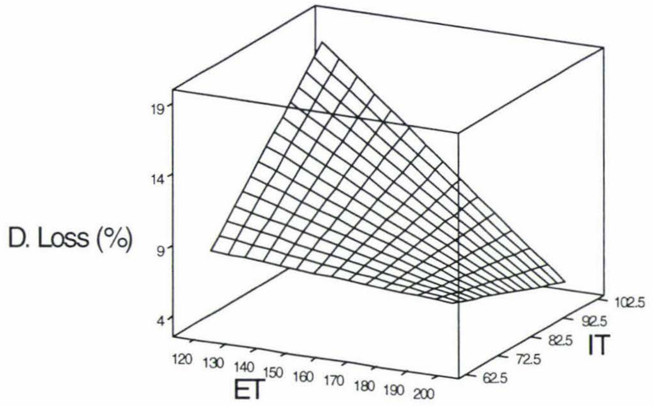


Figure 3.3 Response surface of drip loss (%) for chops

The effect of internal temperature on cooking time is highly significant (P<0.001); in comparison, the effect of external temperature on cooking time is less (P=0.057). There is also an indication of a quadratic effect (P=0.032) of internal temperature (Figure 3.4).

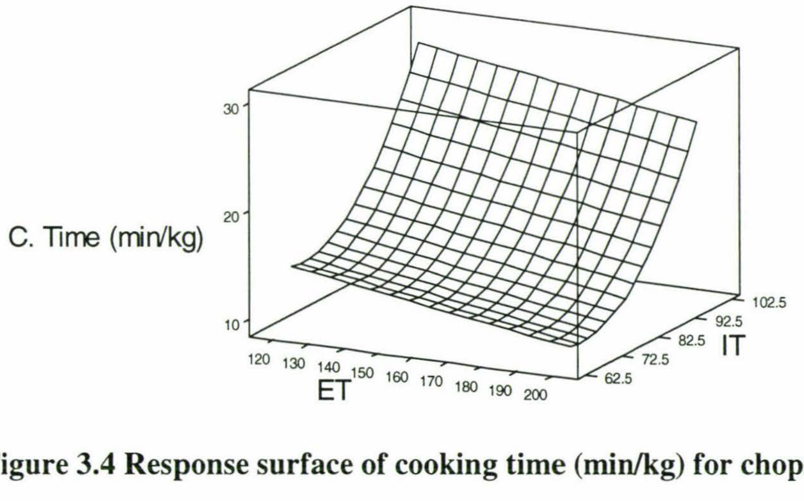


Figure 3.4 Response surface of cooking time (min/kg) for chops

By way of validation the response surface shows that shortest cooking time can be achieved by increasing the external temperature and reducing the internal temperature which is to be expected.

Response surface for b* colour parameter indicates a high in the region of low ET - high IT combination as shown on Figure 3.5. There is also a definite valley in the region of b* value 9.5-10.5.

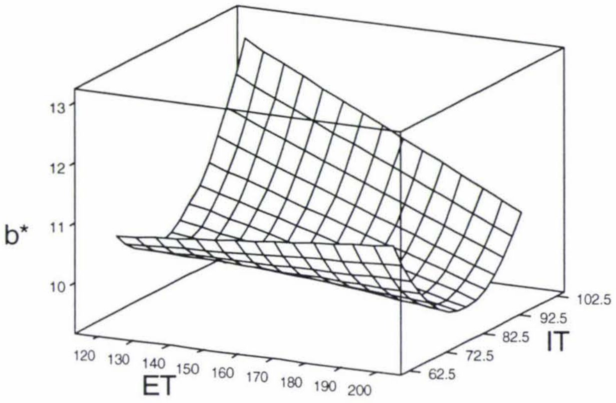


Figure 3.5 Response surface of Hunter colour b* for chops

The effect of external and internal temperatures on cohesiveness, chewiness, colour parameters L* and a*, and Instron shear force was not significant.

B. Principal Component Analysis

Figure 3.6 shows the first two dimensions (PC1 and PC2) from the principal component analysis, explaining 91.4% of the variation of the chop data. The sensory attributes (PCA loading) are shown with red spots and the samples (PCA scores) are shown as blue diamonds. The external temperatures (ET) and internal temperatures (IT) associated with the 9 different cooking codes which represent the different pork chop samples are also shown in the plot. Dimension one explains 80.4 % of the variation and initial juiciness is of greatest importance in explaining this variation.

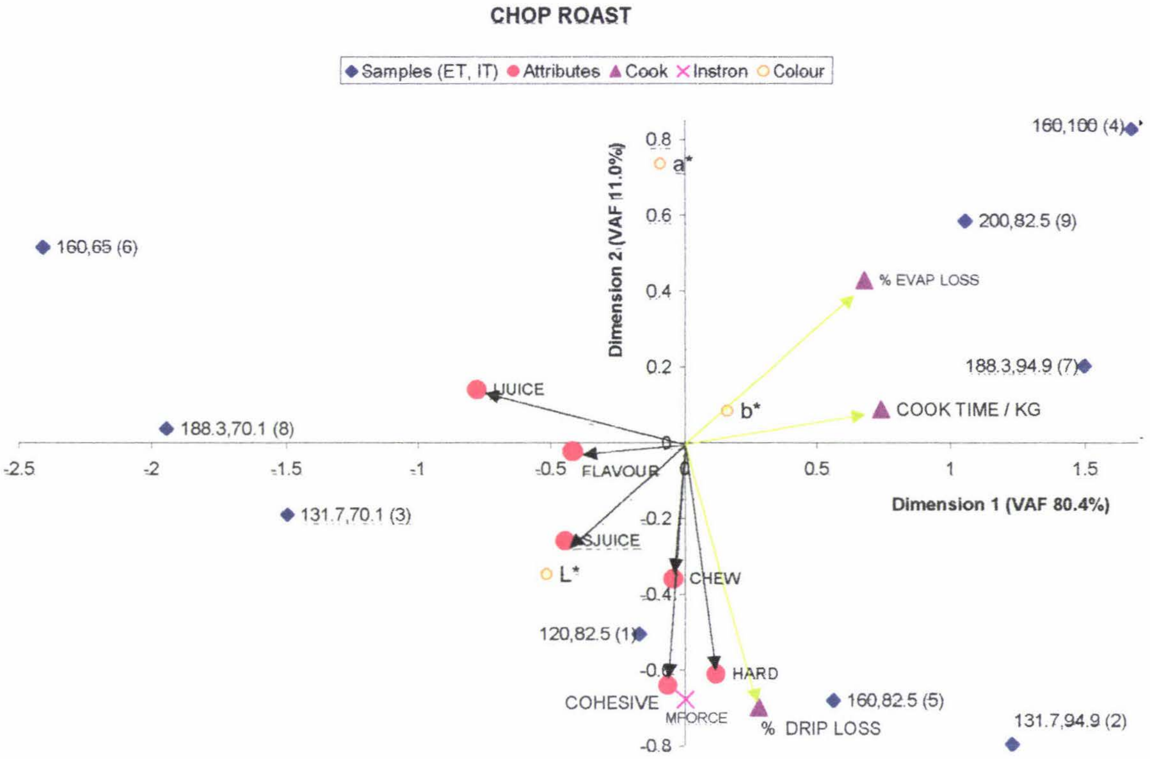


Figure 3.6 Principal component analysis plot for chops

The PCA plots confirm the results obtained by Tukey's testing (Appendix 3.5). Evaporation loss and cooking time are positively correlated with dimension 1. Sample 2($E^{131}I^{94}$), 4($E^{160}I^{100}$), 9($E^{200}I^{82}$), and 7($E^{188}I^{94}$) have high evaporation loss and take more time to cook (min/kg) while samples 6($E^{160}I^{65}$), 8($E^{188}I^{70}$), and 3($E^{131}I^{70}$) are much lower for these characteristics and have a higher initial juiciness.

Dimension 2 which explains 11% of the variation is associated with textural parameters on one side which are measured by sensory evaluation (hardness, cohesiveness, chewiness) and the Instron (shear force). It is also associated with drip loss. The other side of this dimension is associated to Hunter a* (redness) colour parameter. This dimension separates samples 4, 6 and 9 from samples 2 and 5 with the rest in the middle. However these samples are not significantly different in hardness cohesiveness or chewiness as per the results of Tukey's testing, except for the Instron results which show sample 6 required significantly less force (N) to shear than sample 2. There is also significant difference in drip loss between samples 2 and sample 6 and 9.

Hunter colour parameters L* and a* correlate significantly with the second principal component. However b* is not strongly correlated to either of the two first principal components.

C. Attributes Correlation

Although PCA plots gives us an idea of the correlation between attributes it is important to look at the correlation coefficients as shown in Tables 3.7a, and 3.7b. Initial juiciness is positively correlated to sustained juiciness ($p<0.001$) and pork flavour ($p<0.05$). Sustained juiciness is also positively correlated ($p<0.01$) to pork flavour. Though this shows significantly positive relationship between the juiciness parameters it seems that pork flavour is more related to sustained juiciness than to initial juiciness. The higher correlation ($p<0.01$) of pork flavour with sustained juiciness than with initial juiciness ($p<0.05$) may be because pork flavour was evaluated after the 7th chew (which is closer to evaluating sustained juiciness) and not during the 1st chew as for initial juiciness. Cohesiveness is positively correlated ($p<0.01$) to chewiness.

Table 3.7a Correlation of sensory attributes of chops

	I. Juice	Hard	Cohesive	P. Flavour	S. Juice
Hard	-0.48				
Cohesive	0.20	0.47			
P. Flavour	0.77*	-0.32	0.10		
S. Juice	0.94***	-0.22	0.39	0.82**	
Chew	0.20	0.57	0.82**	0.32	0.42

[1] Number of observations = 9, ***$p<0.001$;**$p<0.01$* $p<0.05$

[2] I. Juice-Initial Juiciness; P. Flavour- Pork Flavour; S. Juice-Sustained Juiciness

Hardness is significantly ($p<0.01$) correlated to drip loss and Instron force ($p<0.05$) measurement. Though the correlation is at the 5% significant level it still shows that Instron force measurements can be used for a reliable prediction of sensory hardness for cooked pork chops.

Table 3.7b Correlation of sensory attributes and physical measurements of chops

	I. Juice	Hard	Cohesive	P. Flavour	S. Juice	Chew
Drip Loss	-0.36	0.87**	0.34	-0.04	-0.12	0.52
E. Loss	-0.58	-0.20	-0.34	-0.77*	-0.77*	-0.51
C. Time	-0.74*	0.33	-0.35	-0.51	-0.78*	-0.16
M.Force	-0.01	0.67*	0.49	-0.07	0.14	0.61

[1] Number of observations = 9, ***p<0.001;**p<0.01* p<0.05

[2] I. Juice-Initial Juiciness; P. Flavour- Pork Flavour; S. Juice-Sustained Juiciness; E. Loss-Evaporation Loss; C. Time- Cooking Time; M. Force- Maximum Force

Sustained juiciness and pork flavour are negatively correlated ($p<0.05$) to evaporation loss and both the juiciness parameters are negatively correlated ($P<0.05$) to cooking time. This means an increase in evaporation loss will reduce the pork flavour and sustained juiciness while an increase in cooking time will reduce both the juiciness parameters. Therefore the internal temperature needs to be reduced while roasting pork chops to increase the juiciness and pork flavour.

3.6.1.2 Discussion

In this research a wide range of external and internal temperatures have been used for roasting pork loin chops. Previous work done by Simmons et al (1985) had been carried out using a wide range of internal temperature (60°C - 80°C) but cooked using one particular external temperature (177°C). These researchers have reported a significant decrease in juiciness with an increase in internal temperature from 60°C - 80°C.

Though there is an indication from the regression model coefficients that the influence of external temperature on both the juiciness attributes are insignificant for proper comparison only the groups with similar external temperatures (samples 2 and 3; samples 4, 5 and 6; samples 7 and 8) would be considered. There is a significant decrease in initial juiciness due to the increase of internal temperature from 70.1°C to 94.9°C at oven temperatures 131.7°C and 188.3°C (Appendix 3.5). This trend is similar to the results of Simmons et al (1985). There is also a significant decrease in initial juiciness of chops cooked to 82.5°C and 100°C as compared to 65°C at oven temperatures 160°C which is also similar to the results of Simmons et al (1985). The sustained juiciness follows the same pattern as initial juiciness except for the sample group with external temperature 131.7°C where there is no significant difference.

There were no significant differences in hardness or Warner Bratzler Shear values between the sample groups (samples 2 and 3; samples 4, 5 and 6; samples 7 and 8) which is in contrary to the results of Simmons et al (1985). They reported a significant ($P<0.05$) decrease in tenderness and an increase in Warner Bratzler Shear values due to the increase in internal temperatures.

The correlation between Instron maximum shear force and pork tenderness measured by sensory panelists ranges from -0.27 to -0.78 (Stumpe, 1989 cited in Hovenier et al., 1993). In this experiment the correlation between hardness and Instron force measurement was 0.67. One reason for this low correlation could be the differences in assessment temperature. Sensory assessment of hardness was done at 60°C while Instron force measurements were done at 20°C.

Pork flavour has been reported (Simmons et al, 1985) to be more intense ($p<0.05$) with increased internal temperature due to the increased surface browning and longer cooking time. Webb et al (1961) have stated that higher flavour scores were obtained due to the preconditioning of panel members to prefer the pork flavour developed at higher temperatures because pork has traditionally been prepared to high temperatures. In our experiment pork flavour scores for samples cooked to different internal temperatures (with similar external temperature) did not indicate significant differences. We used Tukey's multiple comparison, which is more conservative, than the Duncan's test used by Simmons et al. (1985). This could be one reason for not showing significant differences for this attribute. Pork (fillet) cooked to an internal temperature of 65°C was used as a reference for pork flavour anchored at eight in the ten point unstructured scale. This was done during the training process due to the request of the panelists and their overwhelming consensus. This method of training may have influenced the panelists to associate the flavour components that occurred at low internal temperatures to pork flavour. It could also mean that our panelists differentiated the pork flavour from cooked flavour because we removed the outer surface of the chop that was in direct contact with the oven racks prior to tasting thereby eliminating the browned surface that imparts most of the cooked caramalised flavour.

There is an overall increase in colour parameter b* (yellowness) due to an increase in internal temperature and a decrease in external temperature.

In conclusion the initial juiciness and sustained juiciness of roasted chops are high at low internal temperatures. The pork flavour is also high at low internal temperature. However internal temperature of 65°C will not guarantee the complete elimination of pink colour in the cooked chops even though there is no significant difference in Hunter a* (redness) color measurement. The significant correlation of initial juiciness ($r=0.77$), sustained juiciness ($r=0.82$), and evaporation loss ($r=-0.77$) with pork flavour shows us that the juiciness of the meat is a predictor of pork flavour. Increasing the external temperature increases evaporation loss and decreases drip loss significantly, but there is only a slight decrease in pork flavour, hardness and cooking time. The objective and subjective measurements of hardness are significantly correlated ($p<0.05$).

These results suggests the use of a moderate external temperature (160°C - 170°C) and a low internal temperature (68°C - 70°C) to obtain cooked chops that are juicy and high in pork flavour.

3.6.2 Fillet

3.6.2.1 Results

The means of sensory and physical measurements for fillets (from the REML analysis) were tested for statistical significance using Tukey's Multiple Comparison method at 95.0% simultaneous confidence intervals. The mean scores (sensory & physical measurements) and Tukey's scores are listed in Appendix 3.6. These results indicate significant differences in the following:

Sensory measurements

Initial juiciness, and sustained juiciness

Physical measurements

Evaporation loss, cooking time, Hunter colour L*, a*, b*

A. Response Surface Analysis

The complexity of ET and IT in influencing differences in sensory and physical attributes can be understood by examining the quadratic regression model coefficients (Table 3.8).

Table 3.8 Q. Regression model coefficients for pork fillet for substitution into equation[1].

	IJUICE		HARD		COHESIVE		FLAVOUR		SJUICE		CHEW	
	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P
A	4.9691	0.000		NS		NS	5.78436	0.000	5.25597	0.000		NS
ET	0.0029	0.625		NS		NS	0.00864	0.078	-0.0017	0.564		NS
IT	-0.1270	0.000		NS		NS	-0.02731	0.021	-0.04695	0.000		NS
ET*ET	-0.0007	0.038		NS		NS	E	NS	E	NS		NS
IT*IT	-0.0038	0.031		NS		NS	E	NS	-0.00193	0.022		NS
ET*IT	E	NS		NS		NS	E	NS	E	NS		NS
R-Sq	91.0%						47.4%		84.3%			
Lack of fit (P)	0.938						0.778		0.818			

	EVAPORATION LOSS		DRIP LOSS		COOKING TIME		COLOUR L*		COLOUR a*		COLOUR b*	
	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P
A	19.7690	0.000	E	NS	83.4591	0.000		NS	6.697	0.000		NS
ET	0.0803	0.054	E	NS	-0.5139	0.022		NS	-0.670	0.392		NS
IT	0.6971	0.000	E	NS	2.2702	0.000		NS	-1.925	0.025		NS
ET*ET	E	NS	E	NS	E	NS		NS	E	NS		NS
IT*IT	0.0223	0.037	E	NS	0.1156	0.036		NS	E	NS		NS
ET*IT	E	NS	E	NS	-0.0434	0.043		NS	E	NS		NS
R-Sq	87.6%				82.2%				47.9			
Lack of fit (P)	0.154				0.240				0.198			

	MAXIMUM FORCE	
	Coef	P
A		NS
ET		NS
IT		NS
ET*ET		NS
IT*IT		NS
ET*IT		NS
R-Sq		
Lack of fit (P)		

A-Constant
ET-External Temperature °C
IT-Internal Temperature
NS- Not Significant
E- Eliminated

[1] $\ddot{Y} = \alpha + \beta_1 IT + \beta_2 ET + \beta_{11} IT*IT + \beta_{22} ET*ET + \beta_{12} IT*ET$

These coefficients indicate a significant influence of internal temperature ($P<0.001$) on initial juiciness. Although there is a significant linear trend a quadratic curvature (Figure

3.7) is also apparent to a lesser extent (P=0.03). For the effect of external temperature on initial juiciness the lack of a significant coefficient indicates no overall increase or decrease in the trend. However there is a quadratic curvature (P=0.038).

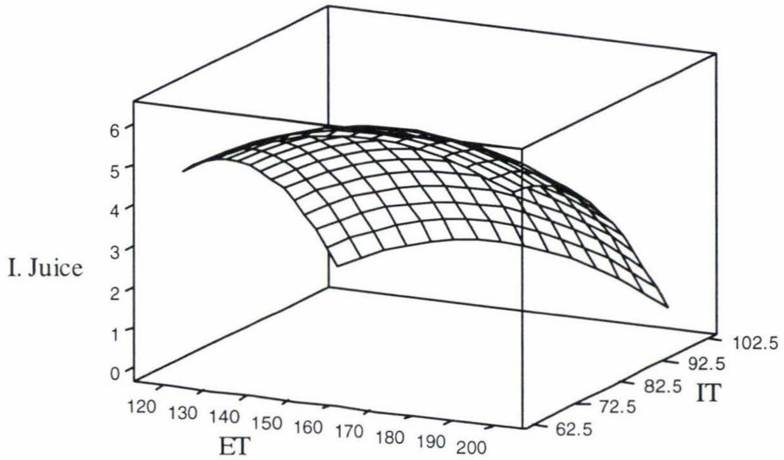


Figure 3.7 Response surface of initial juiciness for fillets

The response surface in Figure 3.7 shows higher initial juiciness at low IT (between ET 150-170 °C).

The effect of external temperature and internal temperature on sensory attribute hardness, cohesiveness and chewiness was not significant. There is also a significant influence of internal temperature on pork flavour (P=0.021) and sustained juiciness (P<0.001). The sustained juiciness and internal temperature is a linear relationship with a quadratic curvature as shown in Figure 3.8.

Similar to initial juiciness higher sustained juiciness and pork flavour for roasted pork fillets can be obtained by cooking at low internal temperatures. While the effect of internal temperature (P<0.001) on evaporation loss is highly significant, the effect of external temperature (P=0.054) on this attribute is only moderately significant. There is also a quadratic curvature (P=0.037) in the trend due to the effect of internal temperature. Highest evaporation loss (%) for fillets is evident at the IT maximum and ET maximum as shown in Figure 3.9.

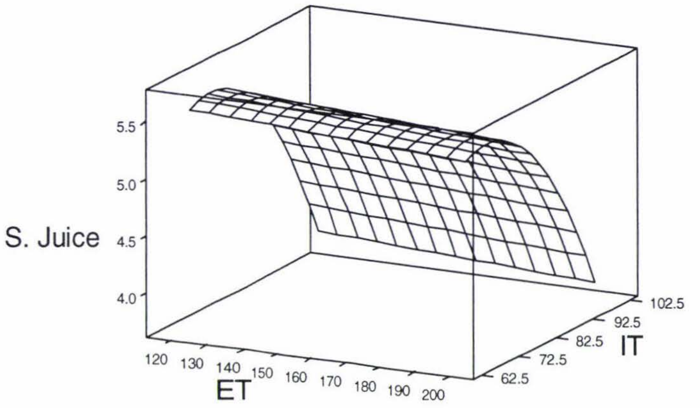


Figure 3.8 Response surface of sustained juiciness for fillets

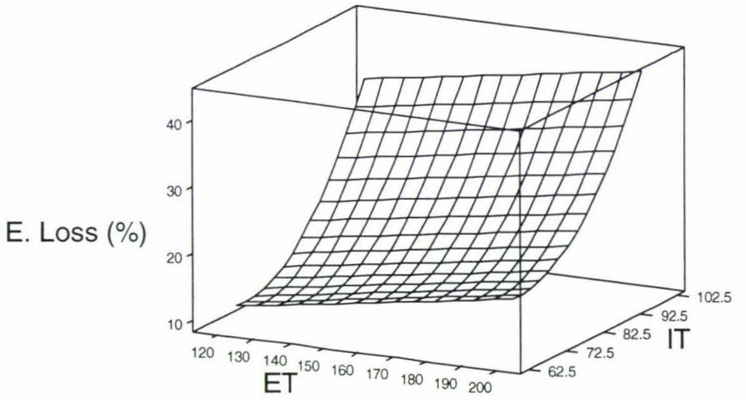


Figure 3.9 Response surface of evaporation loss (%) for fillets

The influence of internal and external temperatures on drip loss is not significant. As expected cooking time of fillet roasts increased due to an increase in internal temperature ($P<0.001$) and a decrease in external temperature ($P=0.022$). The surface plot for cooking time consists of a quadratic curvature due to the effect of internal temperature. There is also an ET-IT combination effect as shown in Figure 3.10.

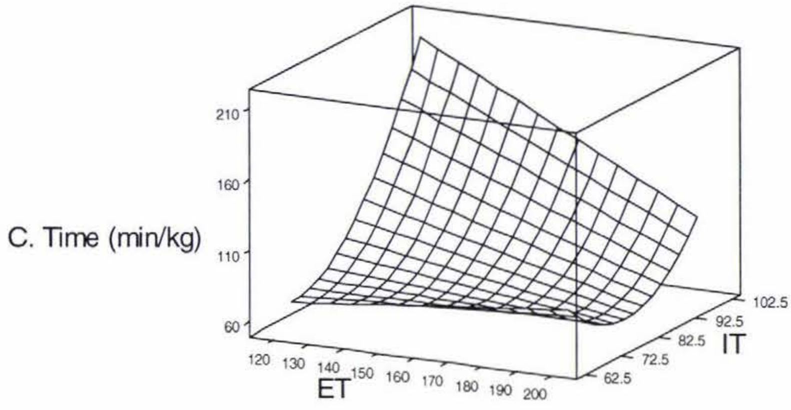


Figure 3.10 Response surface of cooking time for fillets

The influence of internal temperature on colour parameter a* is significant ($P=0.025$). This means to eliminate the redness in cooked fillet roasts only the internal temperature needs to be considered. The effect of external temperature and internal temperature on the hardness and colour objective measurements was not significant.

B. Principal Component Analysis

Figure 3.11 shows the first two dimensions (PC1 and PC2) from the principal component analysis of the fillet data. These two dimensions explain 93.4 % of the variation.

PC 1 separates samples 6 ($E^{160}I^{65}$), 3 ($E^{131}I^{70}$), and 8 ($E^{188}I^{70}$) from samples 2 ($E^{131}I^{94}$), and 4 ($E^{160}I^{100}$). Samples 6, 3, and 8 are high in initial juiciness and samples 2 and 4 are high in evaporation loss and take longer to cook. This confirms the results obtained by Tukey's testing (Appendix 3.6). Colour parameter b* (lightness) is positively correlated and a* negatively correlated with PC1.

Dimension 2 explains 7 % of the variation. This component is associated to textural parameters (hardness, cohesiveness, chewiness), pork flavour with negative loading and sustained juiciness with positive loading. Colour parameter L* and drip loss are both positively correlated with this dimension. This dimension separates sample 1($E^{120}I^{82}$) from sample 6($E^{160}I^{65}$). These samples are significantly different in colour parameter L*.

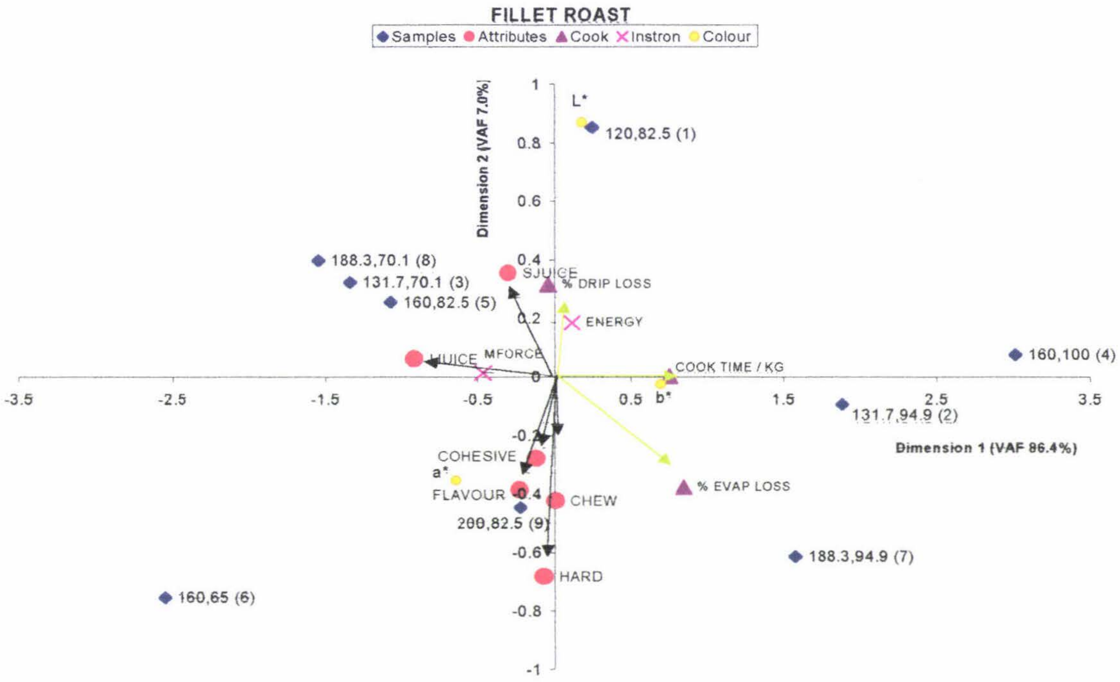


Figure 3.11 Principal component analysis plot for fillets

C. Correlation of Attributes

The correlation coefficients are shown in tables 3.9a, 3.9b and 3.9c. Both the juiciness attributes are highly correlated ($p<0.001$). Pork flavour is positively correlated ($p<0.05$) to initial juiciness and cohesiveness.

Table 3.9a Correlation of sensory attributes of fillets

	I.Juice	Hard	Cohesive	P. Flavour	S.Juice
Hard	0.28				
Cohesive	0.59	0.47			
P.Flavour	0.73*	0.40	0.72*		
S.Juice	0.92***	0.07	0.46	0.59	
Chew	0.00	0.48	-0.03	0.05	-0.31

[1] Number of observations = 9, ***$p<0.001$;**$p<0.01$* $p<0.05$
[2] I. Juice-Initial Juiciness; P. Flavour- Pork Flavour; S. Juice-Sustained Juiciness

Evaporation loss (%) is negatively correlated to initial juiciness ($p<0.01$) and sustained juiciness ($p<0.001$). This relationship supports some of the results mentioned previously that show a pattern between initial juiciness and evaporation loss.

Cooking time (min/kg) is negatively correlated to initial juiciness, cohesiveness, sustained juiciness and pork flavour ($p<0.01$). Evaporation loss is also positively correlated to cooking time. This means a shorter cooking time produces less evaporation loss that translates into an increase in initial juiciness, and sustained juiciness. At this point it should be also noted that evaporation loss affects sustained juiciness more than initial juiciness. Shorter cooking time also increases pork flavour ($p<0.01$) and cohesiveness ($P<0.05$) the former to a greater extent.

Table 3.9b Correlation of sensory attributes and physical measurements of fillets

	I.Juice	hard	Cohesive	P.Flavour	S.Juice	Chew
Drip Loss	0.04	-0.46	-0.14	0.03	0.14	0.09
E.Loss	**-0.84****	0.13	-0.50	-0.58	**-0.91*****	0.31
C.Time	**-0.71***	-0.12	**-0.71***	**-0.87****	**-0.73***	0.39
M.Force	0.47	0.13	0.02	0.44	0.36	-0.08

[1] Number of observations = 9, ***p<0.001;**p<0.01* p<0.05

[2] I. Juice-Initial Juiciness; P. Flavour- Pork Flavour; S. Juice-Sustained Juiciness; E. Loss-Evaporation Loss; C. Time- Cooking Time; M. Force- Maximum Force

Increased L* (lightness) values is associated to lower hardness values ($r=-0.86$, $p<0.01$) and lower chewiness values ($r=-0.68$, $p<0.05$). Colour parameter a* (redness) is positively correlated with initial juiciness ($r=0.66$, $p<0.05$) and b* (yellowness) is negatively correlated to initial juiciness ($r=-0.69$, $P<0.05$) and cohesiveness ($r=-0.75$, $p<0.02$). This indicates the change in colour that occurs during the cooking process from redness to yellowness in terms of Hunter colour parameters.

Table 3.9c Correlation of physical measurements of fillets

	Drip Loss	E.Loss	C.Time
E.Loss	-0.40		
C.Time	-0.09	0.76*	
M.Force	-0.48	-0.19	-0.35

[1] Number of observations = 9, ***p<0.001;**p<0.01* p<0.05

[2] E. Loss-Evaporation Loss; C. Time- Cooking Time; M. Force- Maximum Force

3.6.2.2 Discussion

From the results it is clear that apart from both the juiciness parameters and pork flavour, the increase in internal temperature from 65-100°C does not induce any significant changes in sensory measurements of textural parameters (Hardness, Cohesiveness, & Chewiness) of fillet roasts. The external temperature range of 120-200°C also has no effect on any of the textural properties. Hence fillet can be considered to be more robust to roasting.

A reduction in internal temperature gives a corresponding reduction in evaporation loss, and cooking time and increases both the juiciness parameters. There seems to be a greater reduction in cooking time than an increase in evaporation loss due to an increase in external temperature. The hardness scores for all samples cooked at different IT-ET combinations are between 2.5-4 (Appendix 3.6), which indicates that they are moderately soft in texture. This is mainly due to the type of muscle (*Psoas major*) present in this cut. This muscle has the lowest hydroxyproline (as an indicator of connective tissues) content (Lawrie, 1998) which is inversely correlated with tenderness. There is no evidence of a significant correlation between objective and subjective measurements of hardness of fillet roasts.

The flavour scores for samples cooked to a low internal temperature are around 6-6.5, which is an indication of strong pork flavour prevalent at these temperatures.

To maximise sensory characteristics and reduce the cooking time of fillet roasts cooking to a low internal temperature needs to be considered. However a certain amount of caution should be emphasised while lowering the internal temperature because it is associated to an increase in colour parameter a* (redness). This parameter is an indication of the occurrence of pink colour in cooked pork that is disliked by pork consumers.

Though the trained panel did not do visual colour evaluation, informal inspections during sample preparation have indicated a slight pink colour in fillet roasts cooked to an internal temperature of 65°C.

In conclusion the sensory and physical measurements indicate the use of a moderate external temperature (160°C to 170°C) and a low internal temperature (68°C to 70°C) to obtain an end product that is juicy and high in pork flavour.

3.6.3 Leg

3.6.3.1 Results

Similar to other cuts the means of sensory and physical measurements for leg were tested for statistical significance (Tukey's Multiple Comparison method at 95.0% simultaneous confidence intervals). The mean scores (sensory & physical measurements) and Tukey's scores are listed in Appendix 3.7. These results indicate significant differences in the following:

Sensory measurements

Hardness, cohesiveness, chewiness, pork flavour and sustained juiciness

Physical measurements

Evaporation loss (%), cooking time (min/kg), Hunter colour L*, b*, Instron shear force

A. Response Surface Analysis

The coefficients (Table 3.10) indicate an influence of internal temperature on sensory attribute hardness, cohesiveness and sustained juiciness. The perceived intensity of these attributes decrease due to an increase in internal temperature. Though the above mentioned attributes have a significant linear component in their relationship with internal temperatures there is also a slight quadratic curvature ($P=0.054$) apparent for hardness as shown in Figure 3.12.

Among the physical measurement evaporation loss (%), drip loss (%) and cooking time (min/kg) are influenced by both the external and internal temperatures. While the increase in internal temperature produces an increase in drip loss, an increase in external temperature produces a reduction in the drip loss.

Internal temperature and external temperature both have a significant effect on cooking time ($P<0.001$, and 0.025 respectively). Though the overall relationship here is linear for external temperature there is also a slight quadratic curvature (P=0.018) present as shown in Figure 3.13.

Table 3.10 Q. Regression model coefficients for pork leg roast for substitution into equation[1].

	IJUICE		HARD		COHESIVE		FLAVOUR		SJUICE		CHEW	
	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P
A		NS	4.50827	0.000	3.4452	0.000		NS	3.83647	0.000		NS
ET		NS	-0.00070	0.913	-0.00386	0.546		NS	0.00196	0.571		NS
IT		NS	-0.06512	0.001	-0.08752	0.000		NS	-0.04198	0.000		NS
ET*ET		NS	E	NS	E	NS		NS	E	NS		NS
IT*IT		NS	-0.00341	0.054	E	NS		NS	E	NS		NS
ET*IT		NS	E	NS	E	NS		NS	E	NS		NS
R-Sq			69.7%		76.2%				71.5%			
Lack of fit (P)			0.827		0.615				0.834			

	EVAPORATION LOSS		DRIP LOSS		COOKING TIME		COLOUR L*		COLOUR a*		COLOUR b*	
	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P
A	33.5940	0.000	4.45333	0.000	44.8979	0.000		NS		NS	13.9344	0.000
ET	0.1361	0.000	-0.03227	0.018	-0.1087	0.025		NS		NS	0.0035	0.883
IT	0.3498	0.000	0.06544	0.031	0.7903	0.000		NS		NS	0.1718	0.007
ET*ET	E	NS	E	NS	-0.0056	0.018		NS		NS	E	NS
IT*IT	E	NS	E	NS	E	NS		NS		NS	E	NS
ET*IT	E	NS	E	NS	E	NS		NS		NS	E	NS
R-Sq	86.2%		52.8%		88.3%						46.4%	
Lack of fit (P)	0.135		0.974		0.100						0.678	

	MAXIMUM FORCE	
	Coef	P
A		NS
ET		NS
IT		NS
ET*ET		NS
IT*IT		NS
ET*IT		NS
R-Sq		
Lack of fit (P)		

A-Constant
ET-External Temperature °C
IT-Internal Temperature
E-Eliminate
NS- Not Significant

[1] $\ddot{Y} = \alpha + \beta_1 IT + \beta_2 ET + \beta_{11} IT*IT + \beta_{22} ET*ET + \beta_{12} IT*ET$

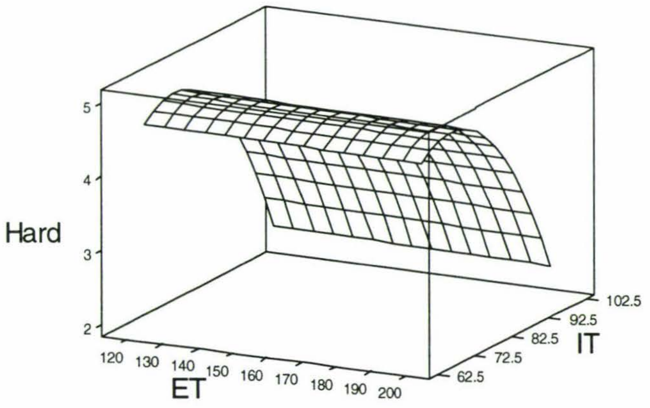


Figure 3.12 Response surface of hardness for leg roasts

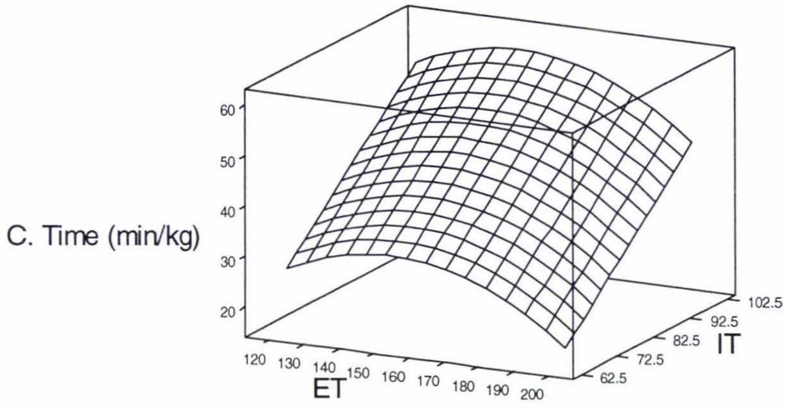


Figure 3.13 Response surface of cooking time for leg roasts

To verify the results lowest cooking time is obtained at the highest ET and lowest IT temperatures. Colour b* is influenced by internal temperature. The effect of external temperatures and internal temperatures on the remaining colour parameters (a* and L*) and Instron textural measurement was not significant.

B. Principal Component Analysis

Figure 3.14 shows the first two dimensions from the principal component analysis. These components explain 94.5 % of the total variation. Dimension 1 appears to be related to sensory and physical measurements of textural properties on one side versus evaporation loss, cooking time, drip loss, and colour parameter b* on the other side. This dimension separates samples 6 ($E^{160}I^{65}$), 3 ($E^{131}I^{70}$), and 8 ($E^{188}I^{70}$) from sample 4 ($E^{160}I^{100}$). Hardness, and cohesiveness in this dimension have higher loading compared to the others and hence contributes in explaining the reason for this separation. This is also shown in the Tukey's test (Appendix 3.7) where samples 6 ($E^{160}I^{65}$), 3 ($E^{131}I^{70}$), and 8 ($E^{188}I^{70}$) are significantly different from sample 4 ($E^{160}I^{100}$) with regard to the above mentioned attributes.

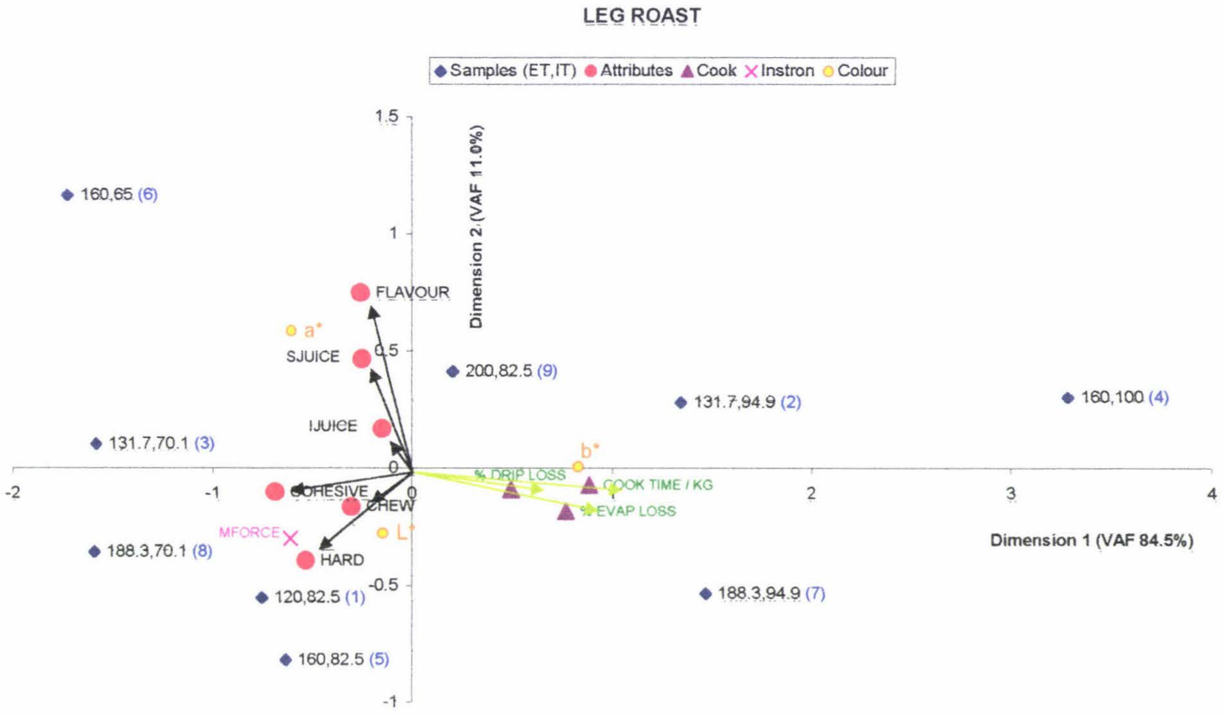


Figure 3.14 Principal component analysis plot for leg roasts

The second dimension, which explains 11% of the variation, is associated with both the juiciness parameters, and pork flavour that have positive loading. This dimension separates sample 6 ($E^{160}I^{65}$) from sample 5 ($E^{160}I^{82}$). Colour parameter a* is associated with both the dimensions.

C. Correlation of Attributes

The correlation coefficients are shown in tables 3.11a, and 3.11b. Initial juiciness is significantly ($p<0.05$) associated with all the other sensory attributes. The correlation of hardness with cohesiveness and chewiness is highly significant ($p<0.001$). Cohesiveness is also highly correlated ($p<0.001$) with chewiness and moderately correlated ($p<0.05$) with sustained juiciness. Pork flavour is more associated ($p<0.01$) to sustained juiciness than to initial juiciness.

Table 3.11a Correlation of sensory attributes of leg roasts

	I.Juice	Hard	Cohesive	P.Flavour	S.Juice
Hard	0.67*				
Cohesive	0.68*	0.96***			
P.Flavour	0.69*	0.46	0.63		
S.Juice	0.79*	0.61	0.73*	0.82**	
Chew	0.75*	0.95***	0.91***	0.51	0.62

[1] Number of observations = 9, ***p<0.001;**p<0.01* p<0.05

[2] I. Juice-Initial Juiciness; P. Flavour- Pork Flavour; S. Juice-Sustained Juiciness

A reduction in evaporation loss is associated ($p<0.05$) to an increase in hardness, cohesiveness and pork flavour. An increase in cooking time is more associated ($p<0.01$) to a decrease in all three sensory textural parameters than to a decrease in juiciness parameters ($p<0.05$).

Table 3.11b Correlation of sensory attributes and physical measurements of leg roasts

	I.Juice	Hard	Cohesive	P.Flavour	S.Juice	Chew
Drip Loss	-0.57	-0.49	-0.42	-0.29	-0.65	-0.54
E.Loss	-0.58	-0.68*	-0.78*	-0.71*	-0.56	-0.61
C.Time	-0.72*	-0.86**	-0.84**	-0.64	-0.76*	-0.87**
M.Force	0.64	0.69*	0.56	0.12	0.45	0.73*

[1] Number of observations = 9, ***p<0.001;**p<0.01* p<0.05

[2] I. Juice-Initial Juiciness; P. Flavour- Pork Flavour; S. Juice-Sustained Juiciness; E. Loss-Evaporation Loss; C. Time- Cooking Time; M. Force- Maximum Force

Instron force measurements are correlated ($p<0.05$) to sensory hardness and chewiness. Colour parameter a* is positively correlated with initial juiciness ($r=0.82$, $p<0.01$), pork flavour ($r=0.75$, $p<0.05$) and sustained juiciness ($r=0.90$, $p<0.001$). Colour parameter b* is negatively correlated with both the juiciness parameter ($r=-0.75$, $p<0.05$), hardness ($r=-0.79$, $p<0.05$), cohesiveness ($r=-0.80$, $p<0.01$) and chewiness ($r=-0.85$, $p<0.01$).

3.6.3.2 Discussion

This research was done using a wide range of internal (65°C-100°C) and external (120°C-200°C) temperatures. Wood et al (1995) have indicated that oven temperatures of 170°C, 180°C, and 190°C had no effects on eating quality of leg roasts. Similar indications are evident from our research because the regression coefficients for external temperature are not significant for sensory attributes. However these results are in contrast with the findings of Larson et al. (1992) who reported low oven temperatures yielded a juicier, more tender and flavourful product. This difference in results may be due to the use of oven bags by Larson et al. (1992) for cooking the leg roast.

Larson et al. (1992) investigated the effects of oven temperatures 82°C, 93°C, 121°C, and 163°C on fresh pork leg roasts cooked to 74°C internal temperature in oven bags. It should be also noted that Wood et al (1995) and our research studied *Gluteobiceps* muscle and Larson et al (1992) was done on *Semitendinosus* muscle.

Though the influence of external temperature on all sensory attributes are insignificant in our research, for proper comparison with other literature on leg roasts only the groups with similar external temperatures [samples $2(E^{131}I^{94})$ and $3(E^{131}I^{70})$; samples $4(E^{160}I^{100})$, $5(E^{160}I^{82})$ and $6(E^{160}I^{65})$; samples $7(E^{188}I^{94})$ and $8(E^{188}I^{70})$] would be considered.

Juiciness explained by Haymann et al. (1990) and Larson et al. (1992) is the moisture release upon chewing which is similar to the sensory attribute sustained juiciness than to initial juiciness (in our experiment). There is an increase in sustained juiciness due to a decrease in internal temperature (significant only between 65°C and 100°C). This increase is similar to Haymann et al (1990), Wood et al. (1995) and Carlin et al. (1968). However these researchers have reported a much greater difference in juiciness due to internal temperature.

There is a significant decrease in hardness due to an increase in internal temperature (significant between 70°C and 94.9°C, 65°C and 100°C). This trend is similar to the results of Bramblett et al. (1970) who have reported higher tenderness scores ($p<0.05$) for ham roasts cooked to 85°C than for those to 76.6°C. The greater difference reported within a shorter temperature difference by Bramblett et al. (1970) could be due to the conservativeness of different statistical tests used for multiple comparisons. However the trend of decrease in hardness due to an increase in internal temperature is in contrary to the results of Haymann et al (1990), and Wood et al. (1995).

The general agreement among researchers is that meat tenderness reduces as end point temperatures increase. This occurs due to the shrinkage of collagen heated above 60°C causing a contracture of the collagen sheath and an exudation of moisture from the myofibrils (Davey and Gilbert, 1974). This exudation of moisture is responsible for the toughening of the myofibrils and allows greater interaction of the protein and greater possibilities for cross-linking and hardening reactions (Davey and Gilbert, 1974). Our results show an opposite trend in tenderisation. At higher end point temperatures, the meat was crumbly and could not be cut into regular cubes. This could be because of the decrease in muscle fiber diameter, decrease of sarcomere length and finally increased disintegration of muscle fibers at higher internal temperatures (Hearne et al. 1978, using Bovine *Semitendinosus* muscles) causing a decrease in hardness. Hence, the decrease in hardness indicates the fact that the rate of thermal degradation of the muscle (both connective and myofibrilar components) more than counteracts for the loss of moisture (that causes a hardening effect). The highly significant ($p<0.001$) correlation of cohesiveness with hardness is a clear indication of muscle fiber disintegration. At internal temperatures of 100°C ($E^{160}I^{100}$) and 94.9°C ($E^{131}I^{94}$), ($E^{188}I^{94}$) cohesive ratings are 1.2, 2.31, and 2.4 which shows that it breaks apart very easily. It is also clear that the differences in cohesiveness due to end point temperature were much greater than the difference in hardness.

Haymann et al. (1990), and Wood et al. (1995) have indicated a significant increase in pork flavour between internal temperatures 65°C and 82.2°C. In our experiment the mean pork flavour scores of leg roast cooked to nine different cooking conditions show significant differences. However the effect of external temperature or internal temperature on this attribute is not significant. This means there has been factors other than external and internal temperatures that has contributed to the differences in the pork flavour scores for leg roast. This needs to be investigated in the future.

The higher correlation ($p<0.01$) of pork flavour with sustained juiciness than with initial juiciness ($p<0.05$) may be because pork flavour was evaluated after the 7th chew (which is closer to evaluating sustained juiciness) and not during the 1st chew as for initial juiciness. Sustained juiciness as explained by Weir (1960) is largely due to the stimulatory effect of fat on salivation. This stimulatory effect could also be a contributing factor for the correlation of pork flavour with sustained juiciness since the fat component could introduce a higher concentration of the volatile and the non-volatile components of pork flavour.

One score for sensory hardness is a composite of several mouth impressions (Cover et al., 1962b). The success of an instrument to measure this depends on the closeness of its relation to human impressions of hardness. In this experiment the correlation between Hardness and Insron shear force measurement (N) is significant ($r=0.69$, $p<0.05$) which suggests that Warner Bratzler shear measurements can be used to predict the hardness of leg roasts. The chewiness ($r=0.73$, $p<0.05$) is also correlated to Insron shear force measurement (N).

Larson et al. (1992) have reported a significant decrease in cooking time (min/kg) as oven temperatures increased from 82°C to 163°C for pork leg roasts. Similarly, our research shows the decrease in cooking time due to the increase in external temperatures (oven temperature) between 120°C - 200°C. The influence of cooking time on most of the sensory attributes is greater than the influence of evaporation loss on these sensory attributes. Hence greater importance should be given to the former parameter in determining the optimum cooking conditions for leg roasts.

An increase in cooking time decreases hardness, which is desirable but decreases juiciness, which may not be desirable from the customers' point of view. Increase in cooking time is more influenced by the increase in internal temperature ($P<0.001$) than by the decrease in external temperature ($P=0.025$).

From this discussion cooking at lower internal temperature of 65°C produces an end product significantly high in sustained juiciness, which is also hard and cohesive. The cooking time and evaporation loss are also less. On the other hand higher internal temperature of 100°C produces an end product significantly low in sustained juiciness, which is also soft, and breaks apart easily. The cooking time and evaporation losses are high. Hence a temperature between 65°C and 100°C needs to be selected to produce a balancing effect. Giving priority to cohesiveness (because of its greater difference among cooking conditions), hardness, sustained juiciness and finally the cooking time (min/kg) a moderate to high external temperature (180°C - 190°C), and a moderate internal temperature (80°C - 85°C) will provide an end product soft in texture with moderate juiciness.

3 .6.4 Loin

3.6.4.1 Results

The mean scores for sensory & physical measurements obtained from REML analysis and Tukey's scores (Tukey's Multiple Comparison method at 95.0% simultaneous confidence intervals) are listed in Appendix 3.8. These results indicate significant differences in the following:

Sensory measurements
Initial juiciness, hardness, cohesiveness, chewiness, and sustained juiciness

Physical measurements
Evaporation loss (%), cooking time (min/kg), Hunter colour L*, b*, Instron shear force

A. Response Surface Analysis

The quadratic regression model coefficients (Table 3.12) indicate an effect of internal temperature on sensory attributes related to texture only.

For external temperature, the lack of a significant coefficient indicates, no overall linear trend between sensory attributes and external temperatures. However there is a quadratic curvature in the trend between external temperature and hardness (P=0.010) and external temperature and chewiness (P=0.069) as shown in figures 3.15 and 3.16.

These Figures show that the values for hardness and chewiness are low between 150°C - 170°C ET.

Table 3.12 Q. Regression model coefficients for pork loin roast for substitution into equation[1].

	IJUICE		HARD		COHESIVE		FLAVOUR		SJUICE		CHEW	
	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P
A		NS	3.23571	0.000	3.29860	0.000		NS		NS	4.70475	0.000
ET		NS	-0.00310	0.671	0.00036	0.962		NS		NS	-0.00635	0.244
IT		NS	-0.05421	0.007	-0.06401	0.003		NS		NS	-0.02989	0.028
ET*ET		NS	0.00084	0.010	E	NS		NS		NS	0.00039	0.069
IT*IT		NS	E	NS	E	NS		NS		NS	E	NS
ET*IT		NS	E	NS	E	NS		NS		NS	E	NS
R-Sq			65.6%		53.6%						52.1%	
Lack of fit (P)			0.434		0.151						0.135	

	EVAPORATION LOSS		DRIP LOSS		COOKING TIME		COLOUR L*		COLOUR a*		COLOUR B*	
	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P
A	27.7947	0.000		NS	59.8193	0.000		NS		NS	12.7524	0.000
ET	0.1270	0.000		NS	-0.1873	0.005		NS		NS	-0.0132	0.527
IT	0.4785	0.000		NS	1.0623	0.000		NS		NS	0.1620	0.005
ET*ET	E	NS		NS	E	NS		NS		NS	E	NS
IT*IT	E	NS		NS	E	NS		NS		NS	0.0080	0.071
ET*IT	E	NS		NS	E	NS		NS		NS	E	NS
R-Sq	96.3%				87.3%						60.5%	
Lack of fit (P)	0.974				0.411						0.782	

	MAXIMUM FORCE	
	Coef	P
A	27.7991	0.000
ET	0.1263	0.049
IT	-0.2978	0.043
ET*ET	0.0061	0.017
IT*IT	E	NS
ET*IT	0.0379	0.001
R-Sq	80.7%	
Lack of fit (P)	0.364	

A-Constant
ET-External Temperature °C
IT-Internal Temperature
E- Eliminated
NS- Not Significant

[1] $\ddot{Y} = \alpha + \beta_1 IT + \beta_2 ET + \beta_{11} IT*IT + \beta_{22} ET*ET + \beta_{12} IT*ET$

Figure 3.15 Response surface of hardness for loin roasts

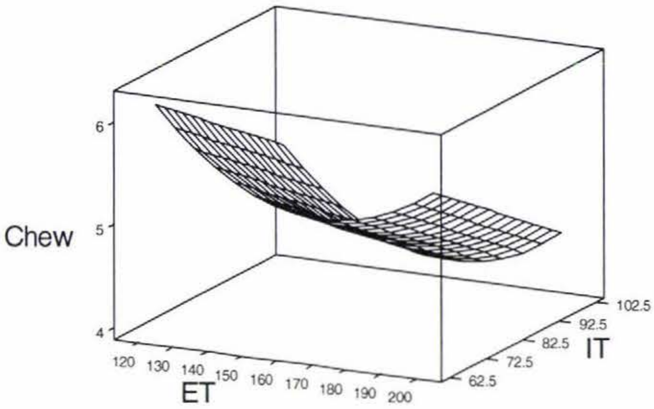


Figure 3.16 Response surface of chewiness for loin roasts

Among the physical measurements evaporation loss (%) and cooking time (min/kg) are significantly influenced both by the external and internal temperatures.

An increase in internal temperature influences an increase in colour measurement b* (P=0.005). There is also a quadratic effect in the increase of b* measurement due to the influence in internal temperature as shown in Figure 3.17.

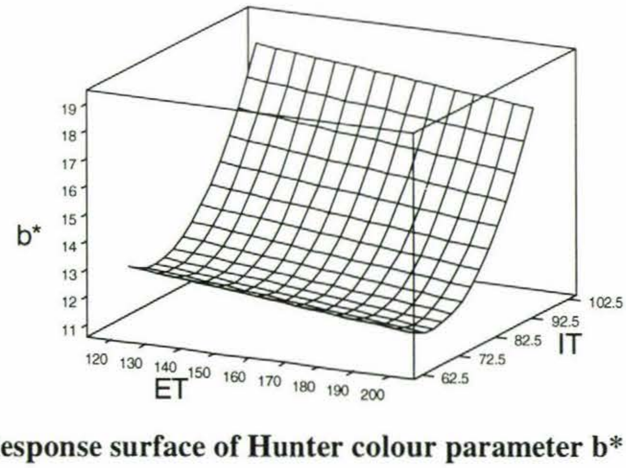


Figure 3.17 Response surface of Hunter colour parameter b* for loin roasts

Response surface for Instron measurement (Figure 3.18) shows the saddle effect where lower values for force measurements were obtained at the lowest ET 120°C and highest IT 100°C combination and highest ET 200°C and lowest IT 65°C combination.

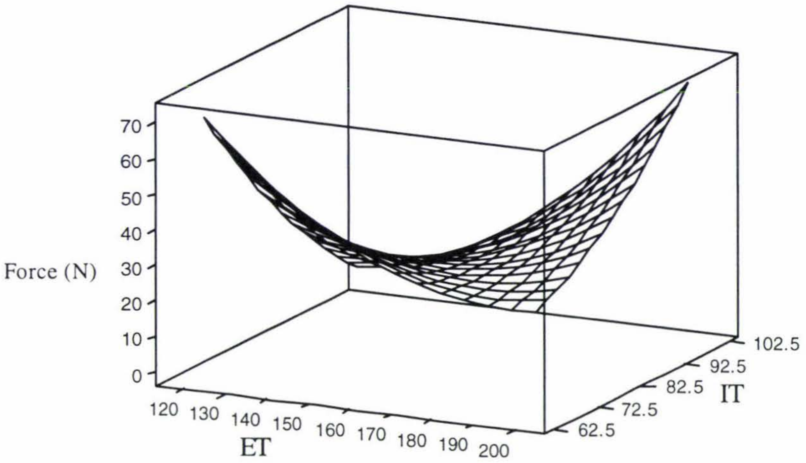


Figure 3.18 Response surface of Instron shear force for loin roasts

The effect of external temperature and internal temperature on juiciness, pork flavour, drip loss, and colour measurement a* and L* was not significant.

B. Principal Component Analysis

Figure 3.19 shows the first two dimensions from the principal component analysis. These components explain 94.4 % of the total variation. Dimension one distinguishes between evaporation loss (%), cooking time (min/kg), colour parameter b* and chewiness, cohesiveness. This dimension separates sample 3($E^{131}I^{70}$) from samples 7 ($E^{188}I^{94}$) and 4 ($E^{160}I^{100}$). Sample 3($E^{131}I^{70}$) is associated with the increase in cohesiveness and chewiness and a decrease in evaporation loss and b* value while samples 7 ($E^{188}I^{94}$) and 4 ($E^{160}I^{100}$) are also associated with the same attributes but with directly opposite trends.

Dimension 2, which explains 16 % of the variation is associated with pork flavour and initial juiciness with positive loading. Drip loss and L* value are negatively correlated with this dimension. This component separates sample 1 ($E^{120}I^{82}$) from sample 3 ($E^{131}I^{70}$) with the remaining samples in between the two. Sensory attributes sustained juiciness and hardness are associated to both the dimensions. Colour parameter a* is not well represented by the map.

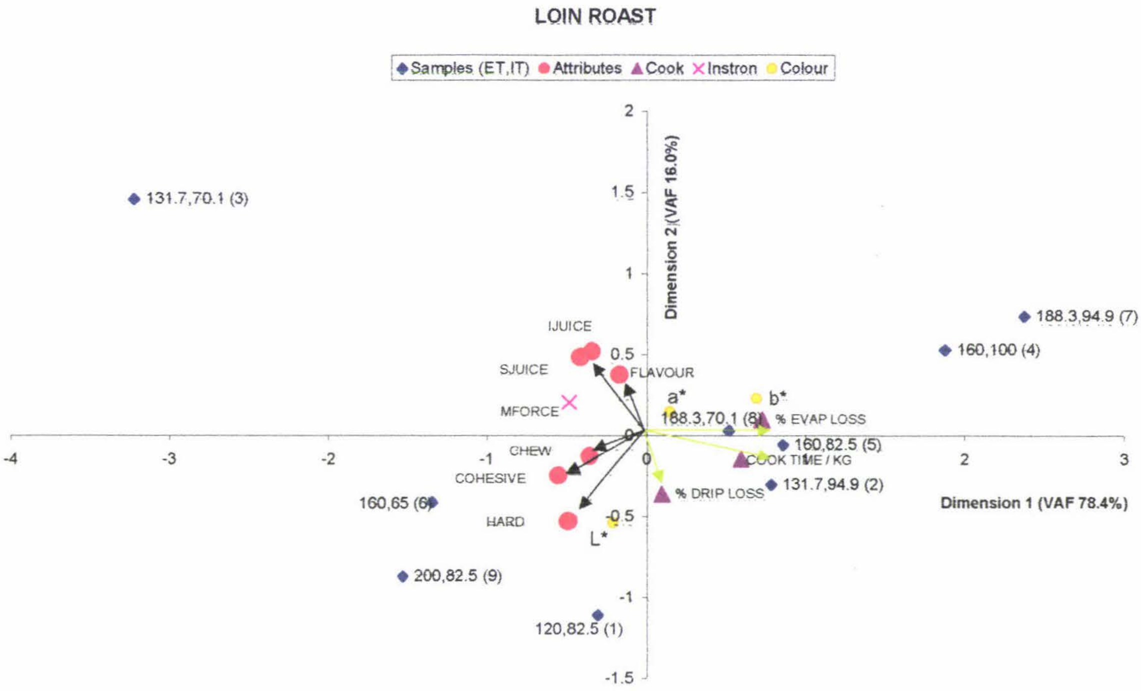


Figure 3.19 Principal component analysis plot for loin roasts

C. Correlation of Attributes

The correlation coefficients are presented in Tables 3.13a, and 3.13b.

Table 3.13a Correlation of sensory attributes of loin roasts

	I.Juice	Hard	Cohesive	P.Flavour	S.Juice
Hard	0.46				
Cohesive	0.69*	0.94***			
P.Flavour	0.75*	0.29	0.47		
S.Juice	0.89**	0.59	0.72*	0.77*	
Chew	0.67*	0.91***	0.91***	0.49	0.74*

[1] Number of observations = 9, ***$p<0.001$;**$p<0.01$* $p<0.05$

[2] I. Juice-Initial Juiciness; P. Flavour- Pork Flavour; S. Juice-Sustained Juiciness

Initial juiciness is strongly correlated with sustained juiciness (p<0.01) compared to cohesiveness, pork flavour or chewiness (p<0.05). A similar correlation pattern can be observed with sustained juiciness. At this point the lack of correlation of these two juiciness parameters with hardness need to be taken into consideration. This means the influence of juiciness in the initial ease of penetration of the meat by the teeth is rather less, compared to its influence in the ease with which the meat breaks into fragments. All the three textural attributes measured by sensory panels are very highly ($p<0.001$) correlated to each other.

An increase in evaporation loss is associated with a decrease in hardness, cohesiveness and chewiness. Cooking time is negatively correlated with initial juiciness.

Hunter colour parameter b* is negatively correlated with hardness ($r=-0.70$, $p<0.05$), cohesiveness ($r=-0.79$, $p<0.01$), and positively correlated with cooking time ($r=0.79$, $p<0.01$). This indicates the association of b* parameter (yellowness) with loin roasts that has been well done.

Table 3.13b Correlation of sensory attributes and physical measurements of loin roasts

	I.Juice	hard	Cohesive	P.Flavour	S.Juice	Chew
Drip Loss	-0.17	0.02	0.00	-0.34	-0.35	0.10
E.Loss	-0.65	**-0.67***	**-0.73***	-0.10	-0.56	**-0.69***
C.Time	**-0.67***	-0.45	-0.64	-0.38	-0.50	-0.34
M.Force	0.48	0.38	0.39	0.55	0.50	0.43

[1] Number of observations = 9, ***$p<0.001$;**$p<0.01$* $p<0.05$

[2] I. Juice-Initial Juiciness; P. Flavour- Pork Flavour; S. Juice-Sustained Juiciness; E. Loss-Evaporation Loss; C. Time- Cooking Time; M. Force- Maximum Force

3.6.4.2 Discussion

These results indicate greater changes in textural properties than changes in juiciness or pork flavour due to the effect of the nine different cooking conditions. The comparisons made with other literature in this discussion are based only on loin roasts.

Jones et al. (1980) have reported no significant changes in juiciness due to the difference in external temperatures between 121°C and 163°C. Weir et al. (1963) have also reported no significant variation in initial juiciness and sustained juiciness over a range of oven temperatures starting from 148.9°C upto 204.4°C. Likewise the present study reveals no significant influence of external temperature on initial juiciness and sustained juiciness. However, this is in contrary to Zondagh et al. (1986). These researchers using response surfaces have indicated that lowest juiciness values are obtained at an external temperature of 232°C at virtually any selected internal temperature (75°C-95°C). The external temperature used here is 32°C higher than our research, which could be the reason for the difference.

Pengilly and Harrison (1966), and Weir et al. (1963) have shown significant difference in juiciness between internal temperatures 75°C and 85°C cooked at an external temperature of 176.6°C. Similarly Webb et al. (1961) has reported significant differences in juiciness between internal temperatures 65°C and 85°C cooked at the same external temperature. In our research the coefficients from the quadratic regression model do not indicate a significant influence of internal temperature on initial juiciness or sustained juiciness of loin roast. The use of different cooking equipment, cut size, sample preparation procedure are some factors that could be contributing to differences in findings.

The effect of external temperature on initial tenderness has been significant for Weir et al. (1963) between temperatures 176.6°C and 148.9°C, 190.6°C, or 204.4°C. Using lower external temperatures of 93°C, 121°C, 149°C, and 163°C Jones et al. (1980), reported no significant differences in tenderness. The present work does not indicate a significant decrease or increase in hardness due to the effect of external temperature though there is a slight quadratic curvature in the trend.

Weir et al. (1963), and Pengilly and Harrison (1966) have shown no significant differences in initial tenderness due to the effect of internal temperatures. In contrary Webb et al. (1961) have reported a pronounced reduction in tenderness between internal temperatures 65.6°C and 73.9°C. The quadratic regression model coefficients obtained from the present study show a significant reduction in hardness ($P=0.007$) due to the increase in internal temperature evident only between samples 6($E^{160}I^{65}$) and 4 ($E^{160}I^{100}$).

The trend of a decrease in hardness as internal temperature increase, which has been observed in this study, contradicts previous research. A similar explanation given for leg roasts can be applied here too. The decrease in hardness indicates the fact that the rate of thermal degradation of the muscle (both connective and myofibrilar components) more than counteracts for the loss of moisture (that causes a hardening effect). The highly significant ($p<0.001$) correlation of cohesiveness with hardness is a clear indication of muscle fiber disintegration. At internal temperatures of 100°C and 94.9°C sensory scores (cohesiveness) as low as 1.5 to 3.0 have been obtained which is a clear indication of the ease to break apart the muscle structure.

Sampling methods used by researchers for sensory evaluation of loin roasts have been different. Some have used cores (Webb et al., 1961; Pengilly & Harrison, 1966) with different dimensions, cubes (Weir et al., 1963; Zondagh et al., 1986), or wafers (Jones et al., 1980). Though the same sensory response is being measured, variations in sample dimensions can alter the textural perceptions more than the juiciness perceptions finally producing different results. Comparing these results with each other can be ambiguous, leading to misinterpretation.

Pork flavour changes due to the effect of external temperature is not significant in this study which is similar to Jones et al. (1980). Weir et al. (1963) on the other hand have shown a significant rise in flavour quality between external temperatures 148°C and 176.6°C. The effect of internal temperature on pork flavour is also not significant as per the quadratic regression model coefficient which is similar to the results of Weir et al. (1963). However, Webb et al. (1961) and Pengilly and Harrison. (1966) reported significantly higher flavour scores for loin roasts cooked to 85°C than for roasts cooked 65°C. Similarly Haymann et al. (1990) using nine different cuts including loin have reported a significant increase in pork flavour at 82.2°C compared to 65.6°C and 71.1°C.

Most of the above mentioned researchers have based the sensory rating for flavour either on panel liking or cooked flavour. Our trained sensory panel scores are based on the intensity of pork flavour rather than the intensity of cooked flavour, which indicates a profound incomparability with other literature.

Evaporation loss (%) is a function of internal and external temperatures. This study indicates that maximum evaporation losses occur at the maximum external and internal temperatures. This is similar to the results of Zondagh et al. (1986) who have shown the maximum evaporation loss occurring between ET 177°C - 204°C and at IT 96°C. As expected the longest cooking time is at the lowest external temperature and highest internal temperature. The effect on drip loss is not significant which is similar to the results of Zondagh et al. (1986).

The significant relationship of evaporation loss with the textural parameters and not the juiciness parameters indicate that the texture is affected more than juiciness due to evaporation loss in loin roasts.

In conclusion internal temperature has a profound effect on both Cohesiveness (P=0.003), and hardness (P=0.007), followed by chewiness (P=0.028) with minimal effect on juiciness and pork flavour. Considering these factors and the cooking time a moderate to high external temperature (180-190°C) and a moderate internal temperature (80-85°C) will produce an end product that is soft in texture and easy to break apart during mastication.

3.6.5 Shoulder

3.6.5.1 Results

Tukey's Multiple Comparison method at 95.0% simultaneous confidence intervals was used for testing the statistical significance of the means (sensory and physical measurements) obtained from the REML analysis. These are tabulated in Appendix 3.9. These results indicate significant differences in the following:

Sensory measurements

Initial juiciness, hardness, cohesiveness

Physical measurements

Evaporation loss (%), cooking time (min/kg), Hunter colour L*, a*, b*

A. Response Surface Analysis

The quadratic regression model coefficients in Table 3.14 gives an indication of the complexity of ET and IT in influencing changes in sensory and physical attributes.

Table 3.14 Q. Regression model coefficients for pork shoulder roast for substitution into equation[1].

	IJUICE		HARD		COHESIVE		FLAVOUR		SJUICE		CHEW	
	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P
A		NS	3.1267	0.000	3.05193	0.000		NS		NS		NS
ET		NS	0.0024	0.517	0.00214	0.595		NS		NS		NS
IT		NS	-0.04549	0.000	-0.0608	0.000		NS		NS		NS
ET*ET		NS	E	NS	E	NS		NS		NS		NS
IT*IT		NS	E	NS	E	NS		NS		NS		NS
ET*IT		NS	E	NS	E	NS		NS		NS		NS
R-Sq			71.1%		79.5%							
Lack of fit (P)			0.895		0.912							
	EVAPORATION LOSS		DRIP LOSS		COOKING TIME		COLOUR L*		COLOUR a*		COLOUR b*	
	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P
A	32.9807	0.000		NS	50.4505	0.000		NS	4.2342	0.000	12.1190	0.000
ET	0.1784	0.000		NS	-0.2812	0.000		NS	-0.0092	0.437	0.0268	0.060
IT	0.4480	0.000		NS	1.0923	0.000		NS	-0.0632	0.055	0.0586	0.100
ET*ET	E	NS		NS	E	NS		NS	E	NS	0.0001	0.835
IT*IT	E	NS		NS	0.0331	0.009		NS	E	NS	0.0083	0.026
ET*IT	E	NS		NS	E	NS		NS	E	NS	0.0016	0.374
R-Sq	86.9%				93.0%				40.2%		67.2%	
Lack of fit (P)	0.256				0.316				0.408		0.981	
	MAXIMUM FORCE											
	Coef	P										
A		NS										
ET		NS										
IT		NS										
ET*ET		NS										
IT*IT		NS										
ET*IT		NS										
R-Sq												
Lack of fit (P)												

A-Constant
ET-External Temperature °C
IT-Internal Temperature
E-Eliminated
NS- Not Significant

[1] $\ddot{Y} = \alpha + \beta_1 IT + \beta_2 ET + \beta_{11} IT*IT + \beta_{22} ET*ET + \beta_{12} IT*ET$

These coefficients do not show a significant effect of internal temperatures and external temperatures on initial juiciness. However the average sensory scores indicate significant differences between some of the cooking conditions. This suggests that there are other variables other than the internal and external temperature producing these differences.

Though the cuts were chosen from carcasses fairly similar in size and quality, one of the variables could be the difference in animals as reported by Jones et al. (1980).

There is a significant influence of internal temperature on hardness (P<0.001) and cohesiveness (P<0.001). There is no effect of internal temperatures and external temperatures on sustained juiciness, pork flavour and chewiness.

Among the physical measurements evaporation loss (%) and cooking time (min/kg) are influenced by both the external and internal temperatures.

An increase in cooking time is caused due to an increase in internal temperature (P<0.001) and due to a decrease in external temperature (P<0.001). There is also a quadratic effect of internal temperature on cooking time as shown in Figure 3.20.

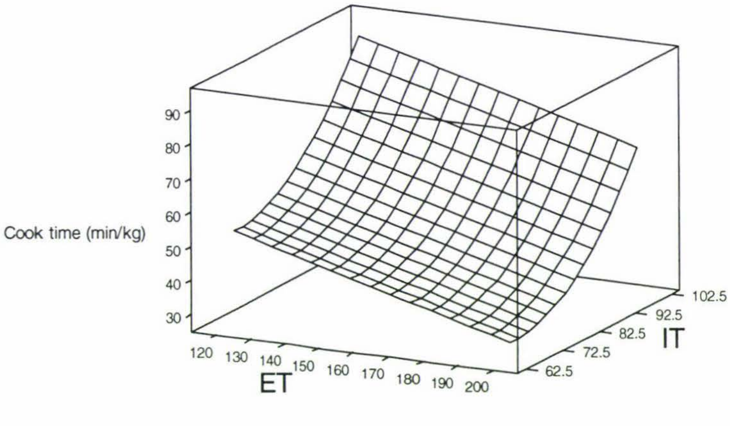


Figure 3.20 Response surface of cooking time (min/kg) for shoulder roasts

An increase in internal temperature produces a decrease in colour measurement a* (P=0.055). However the variation accounted for (R-Sq) is low.

The effect of external temperature and internal temperature on drip loss, colour measurements L* and a*, and objective hardness measurement was not significant.

B. Principal Component Analysis

Figure 3.21 shows the first two dimensions from the principal component analysis. These components explain 90.6 % of the total variation. Dimension one is associated with physical measurements such as evaporation loss (%), cooking time (min/kg), Hunter colour L*,b* on one side versus Cohesiveness, Hardness and Hunter colour a* on the other side. This dimension separates sample 4 ($E^{160}I^{100}$) from sample 6 ($E^{160}I^{65}$). These samples are significantly different in the above mentioned attributes (except for colour a*, b*) which are also confirmed by Tukey's testing (Appendix 3.9).

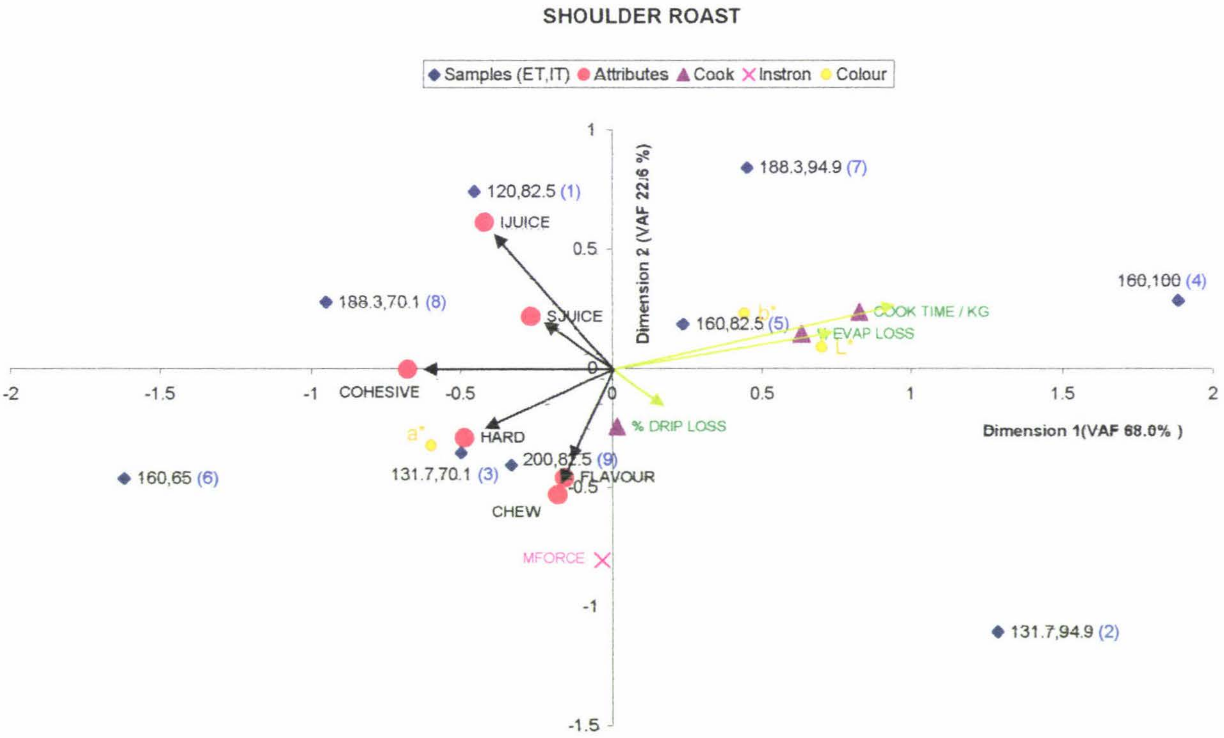


Figure 3.21 Principal component analysis plot for shoulder roasts

Dimension 2 explains 22.6% of the variation. This dimension is associated with initial juiciness with positive loading and chewiness, pork flavour with negative loading separating sample 2 ($E^{131}I^{94}$) from samples 1 ($E^{120}I^{82}$), and 7 ($E^{188}I^{94}$).

C. Correlation of Attributes

Correlation coefficients are shown in Table 3.15a, and 3.15. Initial juiciness is significantly correlated ($p<0.01$) with sustained juiciness. Both these juiciness parameters are correlated with cohesiveness. This indicates the association of juiciness with textural attributes. Meat that does not easily break apart (cohesive) during the chewing process seem to be juicier. For harder samples, the rating of cohesiveness is greater than the rating of chewiness. Chewiness is correlated with pork flavour.

Table 3.15a Correlation of sensory attributes of shoulder roasts

	I.Juice	Hard	Cohesive	P.Flavour	S.Juice
Hard	0.47				
Cohesive	**0.72***	**0.91*****			
P.Flavour	-0.04	0.49	0.33		
S.Juice	**0.84****	0.52	**0.68***	0.24	
Chew	-0.16	**0.70***	0.48	**0.76***	0.14

[1]Number of observations = 9, ***$p<0.001$;**$p<0.01$* $p<0.05$

[2]I. Juice-Initial Juiciness; P. Flavour- Pork Flavour; S. Juice-Sustained Juiciness

Cooking time is negatively correlated ($p<0.05$) to hardness and cohesiveness which indicates an increase in cooking time reduces hardness and cohesiveness. A reduction in hardness is associated to a reduction in chewiness. Pork samples that are less chewy tend to be less in pork flavour.

Table 3.15b Correlation of sensory attributes and physical measurements of shoulder roasts

	I.Juice	Hard	Cohesive	P.Flavour	S.Juice	Chew
Drip Loss	-0.09	-0.06	0.00	0.46	-0.19	0.12
E.Loss	-0.39	-0.58	-0.63	-0.48	-0.50	-0.38
C.Time	-0.47	**-0.89****	**-0.83****	-0.35	-0.41	-0.63
M.Force	-0.52	0.39	0.07	0.34	-0.49	**0.67***

[1]Number of observations = 9, ***$p<0.001$;**$p<0.01$* $p<0.05$

[2]I. Juice-Initial Juiciness; P. Flavour- Pork Flavour; S. Juice-Sustained Juiciness; E. Loss-Evaporation Loss; C. Time- Cooking Time; M. Force- Maximum Force

Instron shear force measurements that were obtained by shearing cores of muscle fibres indicate a correlation with chewiness rather than hardness. The shearing capacity of molars during initial compression of meat is considerably low compared to other teeth. Hence during sensory evaluation of hardness using molars, the action is more of compression than shear. During mastication teeth exhibit a degree of movement in both the horizontal and vertical directions producing compression and shear. This could be a reason for the correlation of Warner Bratzler shear measurement with chewiness.

Colour parameter L* (lightness) is significantly correlated ($r=-0.73$, $p<0.05$) with sustained juiciness and a* (redness) is significantly correlated with hardness ($r=0.68$, $p<0.05$).

3.6.5.2 Discussion

These results of shoulder roasts indicate greater changes in cohesiveness and hardness due to the effect of cooking conditions. The different external and internal temperature combinations do not significantly affect the remaining sensory attributes of shoulder roasts.

The significant decrease in hardness between samples cooked to internal temperature 65°C and 100°C are similar to the results of Bramblett et al. (1970). However, the magnitude of difference in our research is not as great as these researchers. They have indicated a significant increase in tenderness scores for shoulder roasts cooked to internal temperature of 85°C, than for those to 76.6°C. This decreasing trend of hardness due to the effect of internal temperature in shoulder roasts are similar to the loin and leg roasts mentioned previously. Hence, the same reason can be given in explaining this trend.

Texture assessments can be influenced by differences in other sensory characteristics (Brennan, 1988). In this research the significant correlation of juiciness and pork flavour with textural parameters proves this theory. Though there are no significant differences in pork flavour and juiciness with different cooking conditions these attributes in combination with textural attributes can alter the way texture is perceived.

The lack of significant differences in drip loss is also similar to the results of Bramblett et al. (1970). Though internal and external temperatures significantly affect evaporation losses the correlation coefficients indicate no significant relationship between this physical attribute and sensory characteristics. However cooking time that is also significantly affected by internal and external temperatures is highly correlated with hardness and cohesiveness. Hence cooking time needs to be considered when deciding on the optimum cooking condition.

Longer cooking time, though beneficial in reducing the hardness and cohesiveness of meat, will not be convenient for consumers who are looking for quick methods of food preparation. Further more it also increase the consumption of energy. Hence a balance need to be achieved between texture and cooking time.

In conclusion an external temperature range of 180-190°C and an internal temperature range of 80-85°C will provide a tender roast at shorter cooking time.

3.6.6 Scotch

3.6.6.1 Results

Mean scores of attributes obtained from the REML analysis for scotch were tested for statistical significance (Tukey's Multiple Comparison method at 95.0% simultaneous confidence intervals). The mean scores (sensory & physical measurements) and Tukey's scores are listed in Appendix 3.10. These results indicate significant differences in the following:

Sensory measurements

Initial juiciness, hardness, cohesiveness, chewiness, and sustained juiciness

Physical measurements

Evaporation loss (%), cooking time (min/kg), Hunter colour L*, b*, and Instron shear force (N)

A. Response Surface Analysis

These quadratic regression model coefficients (Table 3.16) indicate a significant effect of internal temperature only on both the juiciness parameters and cohesiveness. The effect of internal temperature on initial juiciness and sustained juiciness is highly significant (P=0.001), but with cohesiveness it is moderately significant (P=0.021) with a quadratic effect (P=0.08) as shown in Figure 3.22.

Table 3.16 Q. Regression model coefficients for pork scotch roast for substitution into equation[1].

	IJUICE		HARD		COHESIVE		FLAVOUR		SJUICE		CHEW	
	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P
A	2.6635	0.000		NS	3.9369	0.000		NS	4.5229	0.000		NS
ET	-0.0017	0.774		NS	0.0061	0.355		NS	-0.0020	0.520		NS
IT	-0.06540	0.000		NS	-0.0391	0.021		NS	-0.0307	0.001		NS
ET*ET	E	NS		NS	E	NS		NS	E	NS		NS
IT*IT	E	NS		NS	-0.0031	0.080		NS	E	NS		NS
ET*IT	E	NS		NS	E	NS		NS	E	NS		NS
R-Sq	67.3%				51.9%				62.5%			
Lack of fit (P)	0.731				0.370				0.148			

	EVAPORATION LOSS		DRIP LOSS		COOKING TIME		COLOUR L*		COLOUR a*		COLOUR b*	
	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P	Coef	P
A	30.7793	0.000	3.0676	0.000	82.8193	0.000	55.5041	0.000		NS		NS
ET	0.1198	0.001	-0.01693	0.014	-0.7205	0.000	-0.0282	0.133		NS		NS
IT	0.6016	0.000	0.01384	0.314	2.0063	0.000	-0.0753	0.084		NS		NS
ET*ET	E	NS	E	NS	E	NS	0.0026	0.010		NS		NS
IT*IT	E	NS	-0.00291	0.072	E	NS	E	NS		NS		NS
ET*IT	-0.0055	0.073	-0.00118	0.063	-0.0222	0.067	E	NS		NS		NS
R-Sq	91.0%		64.7%		90.5%		58.9%					
Lack of fit (P)	0.357		0.660		0.108		0.289					

	MAXIMUM FORCE	
	Coef	P
A		NS
ET		NS
IT		NS
ET*ET		NS
IT*IT		NS
ET*IT		NS
R-Sq		
Lack of fit (P)		

A-Constant

ET-External Temperature °C

IT-Internal Temperature

E- Eliminated

NS- Not Significant

[1] $\ddot{Y} = \alpha + \beta_1 IT + \beta_2 ET + \beta_{11} IT*IT + \beta_{22} ET*ET + \beta_{12} IT*ET$

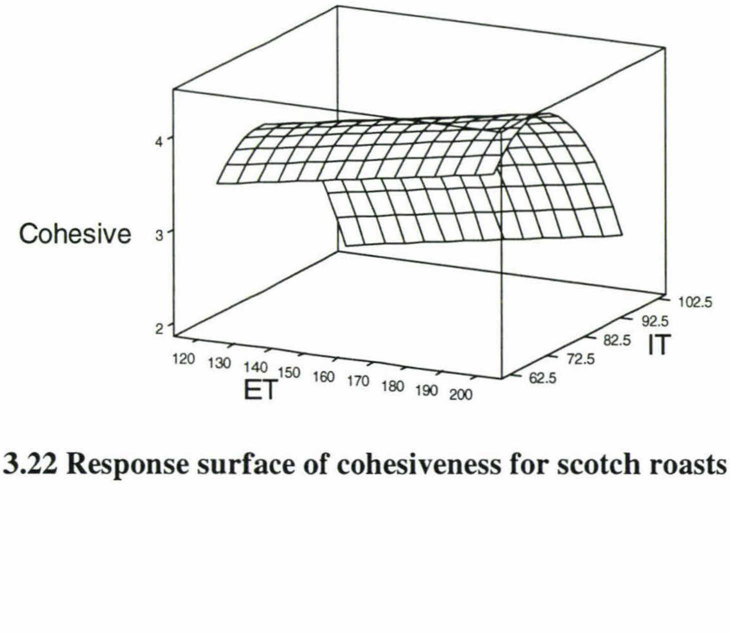


Figure 3.22 Response surface of cohesiveness for scotch roasts

The sensory panel means for hardness and chewiness show significant differences between cooking conditions. However the effect of internal and external temperatures do not seem to be influencing these changes. This suggests that there are other variables other than the internal and external temperature producing these differences. One of the variables could be the difference in animals as reported by Jones et al. (1980).

The coefficients indicate no influence of external temperatures on any of the sensory attributes.

Both the internal and external temperatures significantly affect evaporation loss (P=0.001 and P<0.001 respectively). There is also an ET-IT combined effect as shown in Figure 3.23.

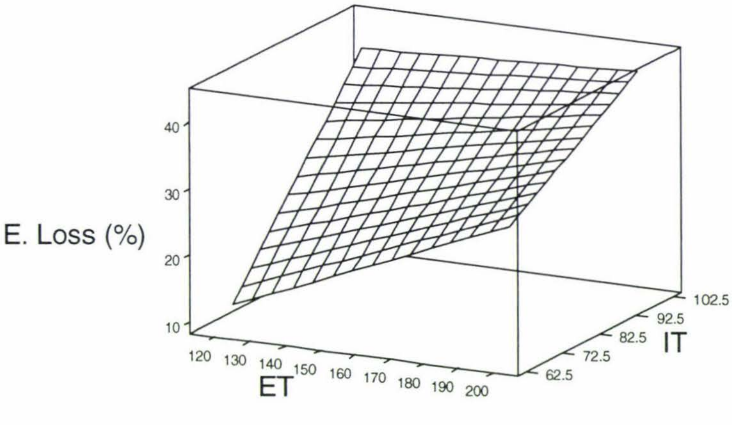


Figure 3.23 Response surface of evaporation loss (%) for scotch roasts

A reduction in drip loss is influence by an increase in external temperature (P=0.014). There is also a quadratic effect of internal temperature and an ET-IT combined effect on drip loss (Figure 3.24).

The effect of internal and external temperature on cooking time is highly significant (P<0.001). A decrease in internal temperature and an increase in external temperature produces an overall decrease in cooking time. There is also an ET-IT combined effect on this attribute (Figure 3.25).

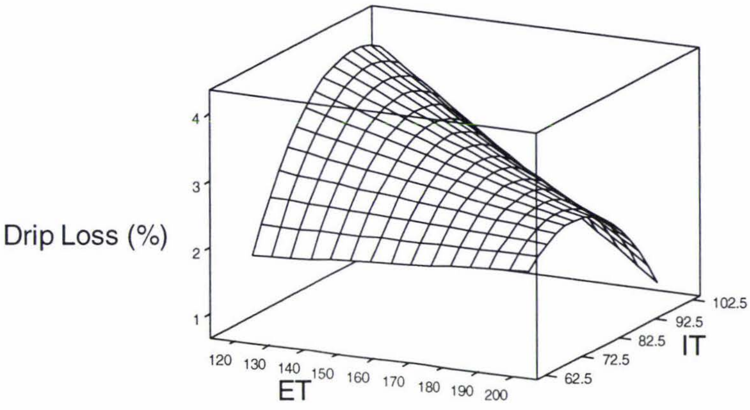


Figure 3.24 Response surface of drip loss (%) for scotch roasts

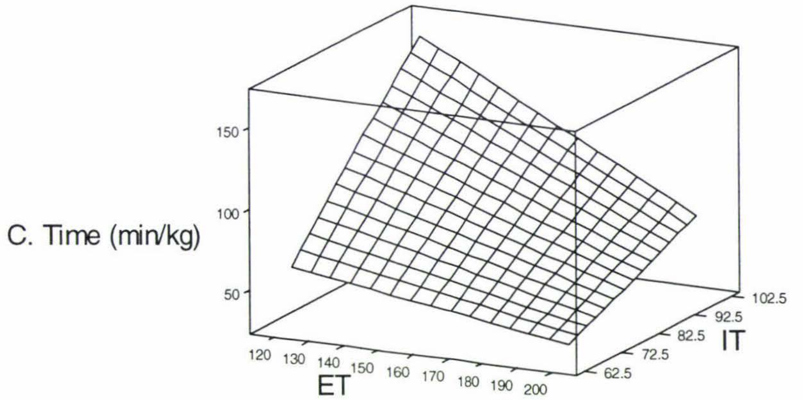


Figure 3.25 Response surface of cook time for scotch roasts

Colour parameter L* is influence by internal temperature. Though there is no linear relationship between external temperature and this parameter a quadratic curvature (P=0.020) is evident from the results (Figure 3.26).

The effect of external temperatures and internal temperatures on colour parameter a* and b* and objective textural measurements was not significant as per the model predictions.

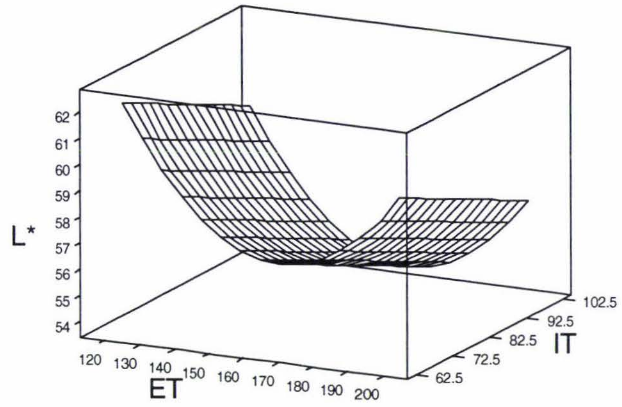


Figure 3.26 Response surface of Hunter colour parameter L* for scotch roasts

B. Principal Component Analysis

Figure 3.27 shows the first two dimensions from the principal component analysis.

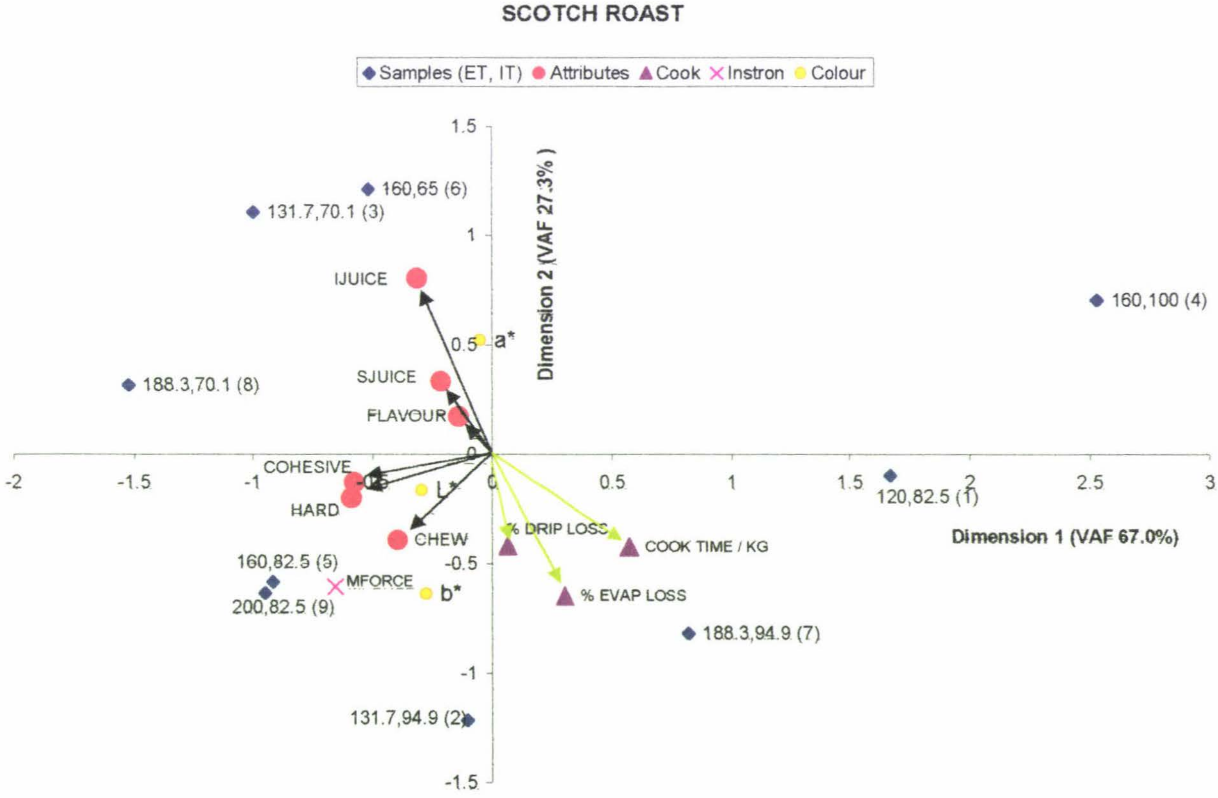


Figure 3.27 Principal component analysis plot for scotch roasts

These components explain 94.3 % of the total variation. Dimension 1 is associated with hardness and cohesiveness with negative loadings. Cooking time (min/kg) is positively correlated with this dimension. This dimension separates sample 4 ($E^{160}I^{100}$) from 8 ($E^{188}I^{70}$) due to significant differences in the above mentioned attributes. This confirms the results obtained by Tukey's testing (Appendix 3.10).

Dimension 2 explains 27.3 % of the variation. This dimension distinguishes between initial juiciness, sustained juiciness, Hunter colour parameter a* (redness) and evaporation loss (%), drip loss (%), Hunter colour parameter b* and objective textural measurements. Sample 2 ($E^{131}I^{94}$) is separated from sample 6 ($E^{160}I^{65}$) in this dimension, which is mainly due to significant differences in initial juiciness.

The variance accounted for both the dimensions (67% and 27.3% respectively) indicates the importance of texture (explained by dimension 1) as well as juiciness (explained by dimension 2) in explaining the variance.

C. Correlation of Attributes

Correlation coefficients indicate a significant ($p<0.01$) correlation between initial juiciness and sustained juiciness. Sustained juiciness is also correlated ($p<0.05$) with pork flavour.

Table 3.17a Correlation of sensory attributes of scotch roasts

	I.Juice	Hard	Cohesive	P.Flavour	S.Juice	Chew	Drip Loss
I.Juice	1.00						
Hard	0.33	1.00					
Cohesive	0.39	0.98***	1.00				
P.Flavour	0.57	0.43	0.39	1.00			
S.Juice	0.87**	0.47	0.55	0.74*	1.00		
Chew	-0.02	0.88**	0.84*	0.27	0.24	1.00	

[1]Number of observations = 9, ***p<0.001;**p<0.01* p<0.05

[2]I. Juice-Initial Juiciness; P. Flavour- Pork Flavour; S. Juice-Sustained Juiciness

The reason for pork flavour being correlated with sustained juiciness and not initial juiciness is because the former two attributes are measured during mastication and just before swallowing. The latter attribute is measured during the initial bite.

Table 3.17b Correlation of sensory attributes and physical measurements of scotch roast

	I.Juice	Hard	Cohesive	P.Flavour	S.Juice	Chew
Drip Loss	-0.32	-0.04	-0.01	-0.62	-0.31	0.29
E.Loss	-0.74*	-0.12	-0.28	-0.03	-0.61	0.10
C.Time	-0.63	-0.47	-0.56	-0.58	-0.61	-0.16
M.Force	-0.19	0.74*	0.69*	0.19	0.14	0.92***

[1] Number of observations = 9, $***p<0.001$;$**p<0.01$* $p<0.05$

[2] I. Juice-Initial Juiciness; P. Flavour- Pork Flavour; S. Juice-Sustained Juiciness; E. Loss-Evaporation Loss; C. Time- Cooking Time; M. Force- Maximum Force

The correlation between hardness and cohesiveness is highly significant ($p<0.001$). Hardness is also correlated ($p<0.01$) with chewiness. This indicates that a significant change in cohesiveness will affect hardness more than chewiness.

Correlation of sensory attributes with physical measurements indicate a decrease in initial juiciness due to an increase in evaporation loss ($p<0.05$).

Warner Bratzler shear force measurements (maximum force) indicate a strong correlation with chewiness ($p<0.001$) and also hardness and cohesiveness ($p<0.05$). The differences in the significance of these correlations could be attributed to the differences in compression and shear force. Measurement of sensory hardness is more related to compression and chewiness though defined as number of chews required to prepare the sample for swallowing is a function of compression and shear force.

3.6.6.2 Discussion

The sensory evaluation results indicate greater variation in initial and sustained juiciness at different cooking conditions. These differences are only caused by the influence of internal temperature. Hence this parameter needs to be taken into consideration while determining the optimum cooking condition. Initial juiciness is also inversely related to evaporation loss (%). Reducing the evaporation loss by reducing the internal and external temperatures will increase initial juiciness.

Apart from cohesiveness the rest of the textural attributes, evaluated subjectively and objectively do not indicate a trend in the change due to the effect of different cooking conditions. Cohesiveness decreases with an increase in internal temperature, which indicates a balance between juiciness and cohesiveness needs to be achieved when deciding on the optimal internal temperature.

In conclusion an external temperature range of 160-170°C and an internal temperature range of 68-70°C will produce a roast that is juicy and easily breaks apart during mastication.

3.7 Conclusions

The information obtained from the response surfaces could be used for assessing the specific internal and external temperature combination (within the boundaries tested here) that yields desirable levels for the sensory attributes. This information can then be communicated to the catering industry, frozen ready meal manufacturers, and consumers to obtain the required sensory quality during roasting pork. However, in this trial frozen cuts of pork were defrosted and cooked in a commercial type oven. Marinades or sauces were not used. These factors need to be taken into consideration while making recommendations. In some cases where trained sensory panels cannot detect any significant changes due to the effect of internal and external temperature combinations other factors such as the reduction of fuel consumption, convenience, and other cost-cutting measures need to be considered.

The temperature recommendations made in this chapter are based only on trained panel information and physical measurements and does not take into account consumer preferences with regard to texture, juiciness and flavour. This is considered in chapter 4.

3.7.1 Chop Roast

- The regression model coefficients indicate a significant effect of internal temperature (65°C -100°C) only on both the juiciness attributes and pork flavour. The intensity of these attributes decreases due to an increase in internal temperature.
- There is a slight reduction of hardness and pork flavour due to an increase in external temperature (120°C-200°C).

- The recommended external temperature (160-170°C) and internal temperature (68-70°C) is based on minimizing the loss of juiciness and pork flavour in chops.

3.7.2 Fillet Roast

- The regression model coefficients indicate a significant effect of internal temperature (65°C -100°C) only on both the juiciness attributes and pork flavour. The intensity of these attributes decreases due to an increase in internal temperature.
- A linear effect of external temperature (120°C -200°C) is only present in pork flavour.
- Pork fillet cooked to IT 65°C has indicated the presence of pink colour which may not be acceptable to consumers.
- The recommended external temperature (160-170°C) and internal temperature (68-70°C) is based on reducing the occurrence of pink colour and minimizing the loss of juiciness and pork flavour.

3.7.3 Leg Roast

- An increase in internal temperature (65°C -100°C) produces a highly significant decrease in cohesiveness, hardness and sustained juiciness. The effect of external temperature (120°C -200°C) on all the sensory attributes is not significant.
- Cooking to lower internal temperature of 65°C decreases cooking time and evaporation loss and produces an end product significantly high in sustained juiciness, which is also hard and cohesive. Cooking at higher internal temperature of 100°C increase cooking time and evaporation loss and produces an end product significantly low in sustained juiciness, which is also soft, and breaks apart easily. Hence a balance need to be achieved by selecting a middle point.
- The recommended external temperature (180-190°C) and internal temperature (80-85°C) is based on reducing cohesiveness, hardness and cooking time without a significant loss in juiciness.

3.7.4 Loin Roast

- Internal temperature (65°C -100°C) has a profound effect on cohesiveness (P=0.003), and hardness (P=0.007), and finally chewiness (P=0.028) of loin roasts.
- The effect of external temperature (120°C -200°C) on these sensory attributes is not significant. However there is quadratic relationship with hardness and chewiness indicating a slight decrease of these attributes at ET between 150-170°C.
- Evaporation loss (%) is negatively ($p<0.05$) correlated ($p<0.05$) with all textural attributes and cooking time ($p<0.05$) is negatively correlated with initial juiciness.
- The recommended external temperature (180-190°C) and internal temperature (80-85°C) is based on reducing the hardness, cohesiveness, chewiness and cooking time.

3.7.5 Shoulder Roast

- Only the internal temperature as per the quadratic regression model coefficients affects sensory attributes of shoulder roasts.
- An increase in internal temperature reduces only the hardness ($P<0.001$) and cohesiveness ($P<0.001$).
- Evaporation loss is not correlated to any of the sensory attributes while cooking time is significantly correlated to hardness ($r=-0.89$, $p<0.01$) and cohesiveness ($r=-0.83$, $p<0.01$).
- The recommended external temperature (180-190°C) and internal temperature (80-85°C) is based on reducing hardness and cohesiveness and cooking time.

3.7.6 Scotch Roast

- The quadratic regression model coefficients indicate significant effect of internal temperature on both the juiciness attributes and cohesiveness. An increase in internal temperature (65°C -100°C) produces a decrease in both the juiciness and increases the cohesiveness. The effect of external temperature (120°C -200°C) on sensory attributes of scotch roast is not significant.

- Except for the negative correlation of initial juiciness ($r=-0.74$, $p<0.05$) with evaporation loss the remaining sensory attributes are not correlated with drip loss, evaporation loss, or cooking time.
- The recommended external temperature (160-170°C) and internal temperature (68-70°C) is based on balancing the amount of loss in juiciness with reduction of cohesiveness.

3.8 Limitations of This Study

This study was done on cooked meat without the use of marinades or sauces. During this trial the following aspects of cooked pork were not investigated.

- The effect of cooking equipment (commercial type oven vs domestic oven) on the sensory and physical measurements.
- The differences between using frozen versus unfrozen meat for cooking.
- The differences between cooking from frozen state versus cooking after defrosting.

Hence while recommending cooking conditions based on this research the above mentioned points need to be taken into consideration.

CHAPTER FOUR

Consumer Preference Mapping of Roasted Pork Cuts

4.1 Introduction

Understanding the effects of roasting conditions on sensory properties of different pork cuts is important. However to define the importance of these sensory properties it is critical to understand consumer perceptions and acceptance (Fishken, 1990). The objectives of this experiment were threefold: (1) to investigate consumer preferences to pork roasts obtained from selected cut and cooking condition combinations; (2) to relate the sensory profile to consumer preference using internal preference mapping. (3) to determine the sensory attributes that are most important for consumer preference formation with regard to cuts of pork that are roasts. This chapter begins with a brief review on linking consumer panel data with trained panel data, which is then followed by the details of the experiment.

4.2 Linking Consumer Data with Trained Panel Data

4.2.1 Background

Food companies are becoming increasingly reliant on consumer feedback in stipulating the sensory requirements of a product. However, for a food product to be successful in an intensely competitive market consumer feedback alone without diagnostic data (e.g., attribute intensity) is not sufficient enough to provide all the direction and in some cases are misleading due to the ambiguity of some consumer terms (Munoz and Chambers, 1993).

While trained sensory judges, provide technical and precise information on sensory attributes of food products, consumers are the only group of people that provide accurate and dependable information on the degree of liking or preference of these products. In the trained panel oriented stage, the focus is on the product (descriptive information) and the production process. In the consumer oriented stage, the focus is on the consumer interpretation of sensory characteristics of foods, and the role of sensory perception on preference formation (hedonic data) (Van Trijp & Schifferstein, 1995). Interchanging the focuses between the groups or expecting a dual focus from either one of the groups may not be technical and specific enough for research guidance. However, this limitation could be addressed by relating the trained panel data with the consumer data. This approach makes best use of the available information because the two sets complement each other. Preference mapping techniques offer the opportunity to investigate this relationship (Schlich, 1995; McEvan, 1996).

4.2.2 Multidimensional Preference Mapping

Multidimensional preference mapping is a graphical format of interpreting hedonic data (MacFie and Thomson, 1988) and consists of two components:

1. based on hedonic data, samples with similarity cluster together in the map and samples that are not similar appear far apart.

2. Vectors related to each consumer's hedonic response are drawn through the space to help understand the different sample positions and the direction of preference.

This technique is useful in understanding the interrelationship among a set of samples but is not appropriate in determining the degree of difference between samples (Lawless & Heymann, 1998).

There are limitations with perceptual maps. For instance consumer perceptions in a perceptual map relate to only the time it was conducted limiting its usefulness to forecast future behaviour (Johnson, 1988). Additionally, the correlation of an individual's preferences with the dimensions of the map is restricted by the extent to which the map relates to his or her perceptions (Lawless & Heymann, 1998).

The designing of the experiment that incorporates several parameters is of paramount importance for preference mapping. Since many product characteristics are interrelated, the preference mapping approach will enable the product developer, to identify the need to adjust a particular attribute and will also indicate the attributes that influence liking.

In new product development this approach is also useful to optimize products and to check that a prototype product is acceptable, and with regard to preference, falls into the correct segment of the market (Helgesen et al., 1997). Gains and Gutteridge (1991) have mentioned that preference mapping can be effective and economical in linking in-house assessment and quantitative market research.

The consumer preference scores for preference mapping are obtained by conducting central location or hall tests, where a reasonable amount of control is maintained in sample presentation that more closely mimics the conditions of the laboratory. The selection of the consumer group for this experiment is entirely dependent on the objective of the experiment and the products target market.

Each consumer is required to assess all of the products presented for the preference scores to be mapped using this procedure (MacFie and Thomson, 1983). The analysis is based on an individual score rather than an average score, thus showing how individual response vary or cluster into similar groups (Greenhoff and MacFie, 1994: Shocker and Srinivasan, 1979). Demographic and product use information are also gathered from consumers that can be incorporated in the analysis at a later stage to understand its effect on overall preferences.

Preference mapping can be divided into two categories, external analysis also known as PREFMAP (Nute, MacFie and Greenhoff, 1988) and internal analysis also known as MDPREF (Carroll & Chang, 1970).

4.2.2.1. Internal Preference Mapping

Data sets exclusively of consumer preference scores, which may take the form of paired comparison, rank and rating data are used for internal analysis (Roskham, 1979). The information obtained from this internal map of consumers and products can be related to descriptive sensory data.

The MDPREF as mentioned by Marketo et al. (1994) is based on the vector model first proposed by Tucker (1960). It is easier to consider this as similar to principal component analysis where the matrix of data consists of products (column) × consumers (rows). Just like principal component analysis MDPREF identifies the major source of variation within the preference data and extracts this as preference dimension one. It then identifies a second preference dimension (orthogonal to the first), and continues similarly until all of the variation in the acceptance data is accounted for. "The individual consumer acceptance vector can be related to the extracted preference dimensions, by the cosine of the angle between an individual preference vector and the dimension reflecting the correlation, and by the length of the vector being proportional to the variance explained" (Greenhoff and MacFie, 1994. page 146). Increased complexity of consumer preferences adds to the number of principal components to be interpreted. Conversely, the synthesis power of the multidimensional analysis diminishes with the number of axis to be explained (McEwan, 1996).

Internal preference mapping as mentioned before is useful to provide a sample map, based only on preference data. However to understand the reasons for preference the attribute scores (obtained from trained panel and / or physical measurements) corresponding to the samples in the preference map have to be correlated with the relevant preference dimensions. The correlation coefficients obtained from this can be used as plotting coordinates to project the sensory or physical attributes as vectors in the map which will elucidate the reasons for preferences. "One criticism that is directed towards internal analysis is that the dimensions are generated on the basis of individual linear preference vectors, that there is no scope for indicating ideal points" (Greenhoff & MacFie, 1994. page

162). However, according to these authors product configurations resulting from internal analysis are suggestive of quadratic relationships and ideal point.

4.2.2.2 External Preference Mapping

External analysis is similar to internal analysis, but relate the two types of information (consumer preference data & descriptive sensory or instrumental data) in opposite order (Carroll, 1980). Basically it is the mapping of acceptability data for each consumer on to an existing perceptual map of the products (Schiffman et al., 1981; Coxon, 1982), usually obtained from descriptive sensory or instrumental data." In fact, the profile space is external to the acceptability data" (McEvan, 1996. page 74).

The data used to generate the sensory product space may be obtained from descriptive sensory analysis methods by using PCA (Arditti, 1997), from free choice profiling data by using Procrustes analysis (Dijkesterhuis, 1997), or from multidimensional scaling of similarity data (Popper and Heymann, 1996).

Regression analysis is used to relate individual consumers' hedonic scores (dependent variable) to the spatial dimensions of the profile space (predictor variable) (Schlich, 1995). Since the profile space is obtained from multivariate procedures such as principal component analysis or generalised procrustes analysis subjecting the data to decompose into smaller number of dimensions the predictor space is a decomposed space (McEwan, 1996).

A series of preference models are obtained by regressing each consumers' hedonic scores. They can be classified into two types depending on the preference behavior, one which fits a linear regression (vector model), and the other which fits a quadratic regression (ideal point model) (McEwan, 1996). The variance accounted for by each model is analysed, and the most appropriate model is identified for each individual consumer (Callier & Schlich, (1995) cited in Lawless and Haymann, 1998). Respondents who have low levels of variance accounted for by the different models are concluded to be unaffected by the variation in the characteristics articulated in the external dimensions, and may be put through a secondary internal preference analysis (Greenhoff & McFie, 1994).

4.2.3 Broader Concerns

When relating consumer data with descriptive sensory or instrumental data making the decision on which preference mapping technique to use is entirely dependent on the experimenter and the objective of the experiment. According to MacFie & Hedderly, "the underlying meaning of external preference mapping is that the sensory profile data is the 'basic truth' observed without error" (MacFie & Hedderly, 1993. page 41). The preference scores of the consumers are assumed to be imperfectly related to these sensory profiles. However, they argue that food products are made to be eaten and enjoyed and that the preference scores may be equally regarded as the 'basic truth' which means internal preference mapping will be the most suitable technique to relate preference to sensory or instrumental measures.

The selection of samples is a key issue in preference mapping. Preference mapping cannot be done with 3-4 samples. The program sometimes handles a minimum of six samples for the vector model and seven to eight for the ideal point model (McEwan, 1996). However a good spread of samples in the map is important for a good model to be fitted to the data. "By increasing the number of samples we should also be presenting consumers with greater variation to stimulate choice, and also increase the confidence of our analyses through increased degrees of freedom" (Greenhoff & MacFie, 1994. page 149).

The consistency of the sample is also important. When selecting samples from the market or direct from the production line sample variations should be minimised by selecting from the same batch for both the consumer and trained panel trial. This also implies that the samples should be of similar age, and served in identical conditions. As mentioned before all samples have to be tasted by the consumers. When there is a wide range of samples (20 –30) that needs to be studied, initially sensory profiling is done on all these samples and a subset that represents the range (12 –16) is selected for consumer trial. It is important to note that in this case that a multivariate analysis on sensory profile data should not be done using the reduced set of samples (McEwan, 1996). Instead coordinates for these samples are taken from the results of the original multivariate analysis done with all the samples.

Conducting consumer tasting panels with large set of samples is time consuming for the experimenter and arises the question of sensory fatigue. Each consumer may need to attend several sessions to complete the analysis and the samples are served in a unique order with an intention of achieving a complete balance of order and position (MacFie et al., 1989).

Tunaley et al. (1988) have reported that only less than 50% of the consumers were able to be fitted using vector and ideal point model and preference mapping did not give any useful information. However at present this technique is being used quite often. This is evident by the number of journal articles and textbooks referenced in this section with regard to this subject.

In the recent years Preference Mapping has been a commonly used technique in the meat industry. For example Beilken et al. (1991a) have used external preference mapping to relate descriptive sensory data of meat patties to consumer acceptability. Helgensen et al. (1997) used both internal and external preference mapping to relate consumer preference data of six different dry fermented lamb sausages to conventional sensory profiling. Marketo et al. (1994) used internal preference mapping to study the liking rating of eight pigmeat products. However, in a search of the literature there hasn't been any evidence of the use of preference mapping to relate consumer acceptability data of different roasted pork cuts to descriptive sensory data.

4.3 Materials and Methods

4.3.1 Selection of Consumer Panel

The consumer trial was conducted in Brisbane, Australia. It was carried out at the Centre for Food Technology (Department of Primary Industries, Queensland) by Sheryle Rogers

(Sheryle Rogers Consulting Pty Ltd). One hundred and one consumers were recruited for the trial that was conducted over two days. Fifty consumers were tested on the first day and the remaining fifty-one were tested two days later. The recruitment of the consumers was based on the following criterions.

- Approximately equal number of males and females.
- Consumers spread over the four socio-economic groups in the greater Brisbane area.
- Consumers to eat pork at least once a fortnight.

4.3.2 Sample Selection

Due to the cost and practical considerations, it was decided that only one session lasting about an hour per consumer was feasible. This allowed a maximum of ten samples to be evaluated by each consumer, served in two groups of five, with a break in between to minimise sensory fatigue.

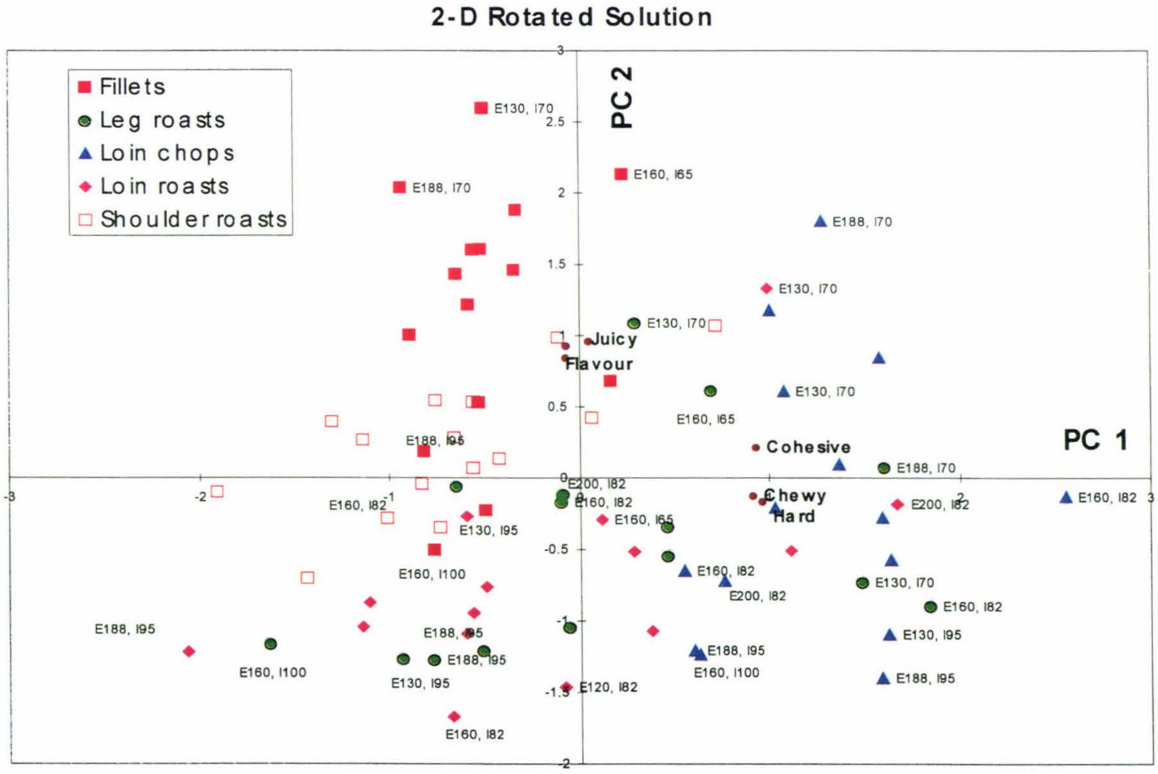


Figure 4.1Combined PCA analysis of all cuts, excluding the scotches (Labels on selected points indicate external and internal temperature combinations (°C))

Sample selection was based around obtaining a maximal spread of sample characteristics thus presenting consumers with significant variation to stimulate choice. From the wide range of samples (9 samples × 6 cuts) that were sensory profiled, a subset (8 samples) that represented the range of characteristics was selected for the consumer trial. This selection was done by examining the plot (Figure 4.1) obtained from the results of a PCA analysis that was performed on the trained panel sensory data for all cuts combined (except the scotches).

The plot in Figure 4.1 shows that the loin chops were generally rated as hard and lacking in pork flavour, while the fillets were rated as soft and flavourful by the trained sensory panel. The large roasts fell in between these cuts, decreasing in hardness and losing flavour as the internal temperature increased. Table 4.1 details the name of the cuts and cooking parameters selected for the consumer trial.

Table 4.1 Cuts and cooking parameter selected for consumer trial

Cut	Target temperatures (°C)		Measured internal temp. (°C) (n = 4-6) DAY 1	Measured internal temp. (°C) (n = 4-6) DAY 2
	External	Internal		
Session 1				
Loin chops - starter	160	82*	93	93
Leg roasts	160	65	66	63
Leg roasts	188	95	90	93
Fillets	160	100	95	97
Loin chops	160	82	85	82
Session 2				
Fillets – starter	160	82	78	82
Fillets	188	70	73	74
Fillets	160	82	85	82
Loin chops	188	95	96	95
Loin chops	188	70*	84	86

* during testing the temperatures were 93°C and 84°C respectively

The first sample (starter sample) in each of the two sets of five samples was not used for the analysis, due to the well-known 'time-order' psychological error, where first samples are found to be scored differently to subsequent ones. This has been shown to occur in consumer testing (Earthy et al., 1997).

It should be taken into consideration that during actual testing two of the measured internal temperatures were significantly higher than the target temperatures that were specified in the design. The starter loin chops in set 1 were taken to 93°C instead of 82°C, and the 70°C loin chops in set 2 were taken to 84°C. Since the consumer evaluation part of this project was sub-contracted to Sheryle Rogers (Sheryle Rogers Consulting Pty Ltd) we had no control in preventing this error happening. However the error made on day 1 were repeated on day 2 to keep the experiment in balance (i.e. to present similar samples to both the consumer groups).

4.3.3 Meat Sample Preparation

The meat for this consumer trial was obtained from KR Darling Downs, Brisbane. The cuts (loin chops, fillets, leg roasts) were obtained from this meat packer to ensure that they would be representative of pork available to the tested consumers. It was requested that the cuts be obtained from female animals of average carcass weight, and normal intra-muscular fat and pH levels. No cuts were to show PSE or DFD characteristics, which are known to affect sensory quality (Heymann et al., 1990).

The fillets were vacuum packed in lots of five and the loin chops (uniform in thickness) in lots of seven. The packed meat were blast frozen and transported to the testing facility at -20°C. At the testing facility the meat was stored at -20°C until needed.

The procedures for defrosting, and cooking the meat samples were the same as those used in the trained sensory panel experiment explained in the previous chapter. After cooking, the chops, fillets and primary top muscle (Gluteobiceps) excised from the leg roast were wrapped completely in aluminum foil and placed in a Bain Marie (60°C) until ready for cutting. The length of time that samples kept in the Bain Marie was minimised.

To prepare the samples for serving, the outer browned surfaces of the meat were removed (about 1-2 m.m). The remaining meat samples were cut into pieces of approximately 20-30 grams in weight and returned to the Bain Marie (60°C) until ready to serve.

4.3.4 Consumer Evaluation

Central location test was conducted under an even light source to allow assessment of meat colour. Except for the starter samples, the presentation order for the remaining four samples in each set was based on a William Latin Square Design (Macfie et al., 1989), achieving a complete balance of order and position every 12 consumers.

Initially, each of the fifty consumers were given the evaluation sheet (Appendix 4.1) for the first set of five samples. Samples were presented monadically on disposable plates serving upto six consumers at a time to minimise cooling. The consumers evaluated the samples using disposable forks, in the presented order, cleansing their palates with a piece of plain water cracker and filtered water between each sample. Consumers marked their degree of liking on a 10 cm unstructured hedonic line scale (Daillant-Spinner, 1996) that was used to evaluate five attributes (Colour, Firmness/Chewiness, Juiciness, Flavour, Overall Feeling). The scale was labeled as "Dislike extremely" at the left anchor, "Neither like nor dislike" at the middle anchor, and "Like extremely" at the right anchor (Appendix 4.1). ' Degree of liking' is called preference in some parts of this chapter for simplification.

After a break of 20 minutes, the consumers were given the second set of five samples and the associated evaluation form, with an attached survey form with demographic and pork consumption questions (Appendix 4.2). After the evaluation of the samples, the consumers were instructed to fill in the survey form before leaving.

A conscious decision was made to use firmness and chewiness together as attribute descriptors for one scale to capture the consumers' preference on tenderness because several mouth impressions are involved in evaluating meat tenderness (Cover et al., 1962b).

4.3.5 Survey Questionnaire Design

The survey form consisted of five pages in total (Appendix 4.2), with the first page recording information on gender, age, employment, and income. The remainder of the survey form consisted of thirteen questions, of which ten questions were regarding the usage of pork, and three regarding the purchase of pork.

4.3.6 Data Analysis

An analysis of variance was performed on the consumer data, and means were tested for statistical significance using Tukey's Multiple Comparison method at 95.0% simultaneous confidence intervals. Following this, the consumer data was also analysed using internal preference mapping (McEwan, 1996). This is similar to a principal component analysis (as mentioned previously) on a matrix of data consisting of samples (objects) and consumers (variables) (Table 4.2).

Table 4.2 Data for biplot analysis (overall preference scores)

Consumer	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
1	4	5	2	6	7	8	5	4
.								
.								
.								
101								

The overall preference data was pretreated by centering (working out the mean score for each person and subtracting that from their scores for each sample, so that each person had a mean score of 0), and then standardising (calculating the standard deviation of the scores given by each consumer, and then dividing their centred scores by that, so that each person's scores had an SD of 1). This was done to ensure that the Preference Map showed differences in the relative scores of the samples, rather than in how much consumers liked pork in general.

The data obtained from these adjustments were imported into Genstat (Genstat 5 Committee, 1993) and a preference map produced using the biplot procedure. The coordinates for the samples and the consumers on the first 2 dimensions of the biplot were plotted to give a map summarising the overall product acceptability information provided by each consumer. Ratings of the trained panel for initial juiciness, sustained juiciness, hardness, cohesiveness, chewiness and flavour were added to the map by correlating the average scores of the samples with the coordinates of the samples on dimension 1 and 2.

Similar analysis was done on the preference ratings of the consumers' for the colour, firmness, juiciness and flavour of the samples. The consumer survey data were summarised and tabulated.

4.4 Results & Discussion – Consumer Taste Panel

The results for consumer taste panel are reported under two sections. The first section encompasses the analysis done on the consumer liking data of the pork samples based on the colour, firmness, juiciness and flavour. Separate measurements of these attributes were done so that each aspect of the product can be considered in detail. The second section contains the analysis of internal preference mapping on the overall acceptability data.

4.4.1 Consumer Liking for Colour, Firmness, Juiciness, and Flavour

The analysis of variance results (Table 4.3) indicate significant differences ($p<0.05$) between samples on the basis of consumer liking for colour, firmness, juiciness and flavour.

Table 4.3 Mean preference scores from consumer testing

Sample	External Temperature (°C)	Internal Temperature Range (°C)	Colour	Firmness or Chewiness	Juiciness	Flavour
Chop	E^{160}	I^{82}	6.01^{bc}	5.09^{b}	4.02^{c}	5.07^{c}
Chop	E^{188}	I^{86}	4.55^{d}	3.18^{c}	2.53^{d}	3.55^{d}
Chop	E^{188}	I^{95}	5.67^{c}	3.25^{c}	2.25^{d}	3.15^{d}
Fillet	E^{188}	I^{74}	6.71^{ab}	7.30^{a}	7.45^{ab}	6.30^{b}
Fillet	E^{160}	I^{82}	6.94^{a}	7.57^{a}	7.50^{ab}	7.31^{a}
Fillet	E^{160}	I^{97}	7.19^{a}	7.96^{a}	7.56^{a}	7.75^{a}
Leg Roast	E^{160}	I^{63}	5.95^{bc}	7.14^{a}	6.82^{ab}	7.07^{ab}
Leg Roast	E^{188}	I^{93}	6.58^{ab}	7.23^{a}	6.71^{b}	7.06^{ab}

[1] Means in the same column with same letter are not significantly different ($p<0.05$)
[2] Unstructured 10cm scale where 0= dislike extremely, 5= neither like nor dislike, and 10= like extremely

Multivariate analysis of sample attributes (colour, firmness, juiciness, flavour) are presented as biplots in Figures 4.2 to 4.5. The first two dimensions accounted to 40-50% of the variation in the data, which is common for this type of analysis (McEwan, 1996).

The sample space is similar for all these maps with the loin chops placed on the left and the fillets on the right and the leg roasts in between. The colour biplots (Figures 4.2a,b) indicate a positive correlation of Hunter Colour b* (yellowness) with colour liking. The correlation of parameter a* (redness) with colour liking is not well explained in the map. Hunter colour parameter L* (lightness) is negatively correlated with colour liking. These indicate that a more acceptable product in terms of colour tend to be dark and yellowish.

The biplots for firmness (Figure 4.3a,b) show hardness, cohesiveness and chewiness as analysed by trained panel are negatively correlated with the consumer liking of firmness. This indicates that consumers like cooked pork that is soft, and that easily breaks apart during chewing (not cohesive or chewy).

Sustained juiciness as analysed by trained panel is more correlated to consumer liking of juiciness compared to initial juiciness according to biplots (Figure 4.4a,b). This is mainly because the consumers evaluated juiciness during the chewing process which is more related to sustained juiciness.

Juiciness as evaluated by trained panelists had two organoleptic components. Firstly it is the sensation of wetness (initial juiciness) that is noticed during the first bite. This occurs due to the rapid release of meat fluid. This is followed by sustained juiciness, largely due to the stimulatory effect of fat on salivation.

The directions of the vector for pork flavour as analysed by trained sensory panel and the consumer flavour liking vectors are apart as indicated in the flavour biplots (Figure 4.5a,b). Though these two attributes are correlated to a certain extent, the main reason for the difference is, the trained panel evaluation was based on the pork flavour, and consumer liking could have been based on the overall flavour and more specifically the cooked flavour.

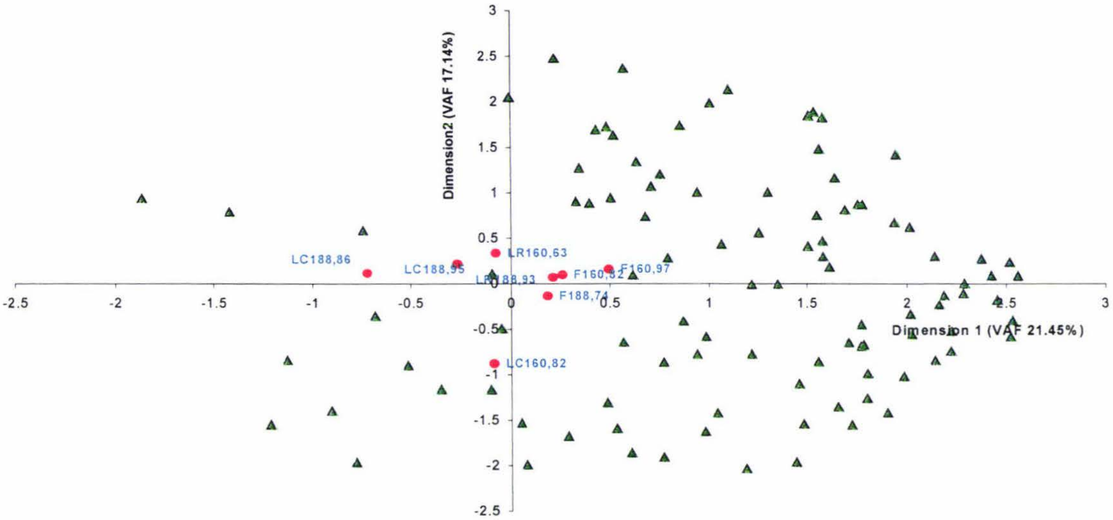


Figure: 4.2a Biplots showing the first two dimensions of consumer preference for colour
Sample (•) space where LC= loin chop; F = fillet; LR = leg roast; numbers show external and internal temperatures, Consumer preference vectors shown as (▲)

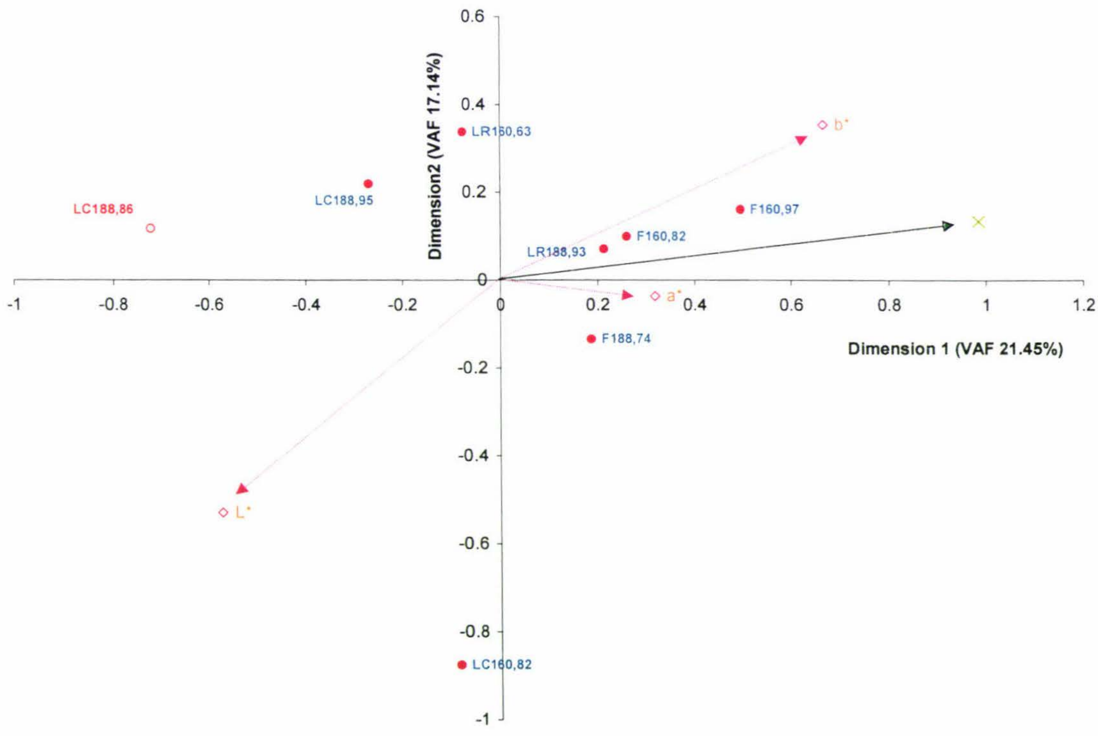


Figure: 4.2b Interpretation of the sample space defined in Figure 4.2a, using Hunter colour measurements
Sample (•) space generated from colour preference data (where LC= loin chop; F = fillet; LR = leg roast; numbers show external and internal temperatures, direction of liking for total samples shown as →, direction of increase in Hunter colour measurements L*, a*, b* are shown as →. (o) sample data not used for correlating with Hunter colour data.

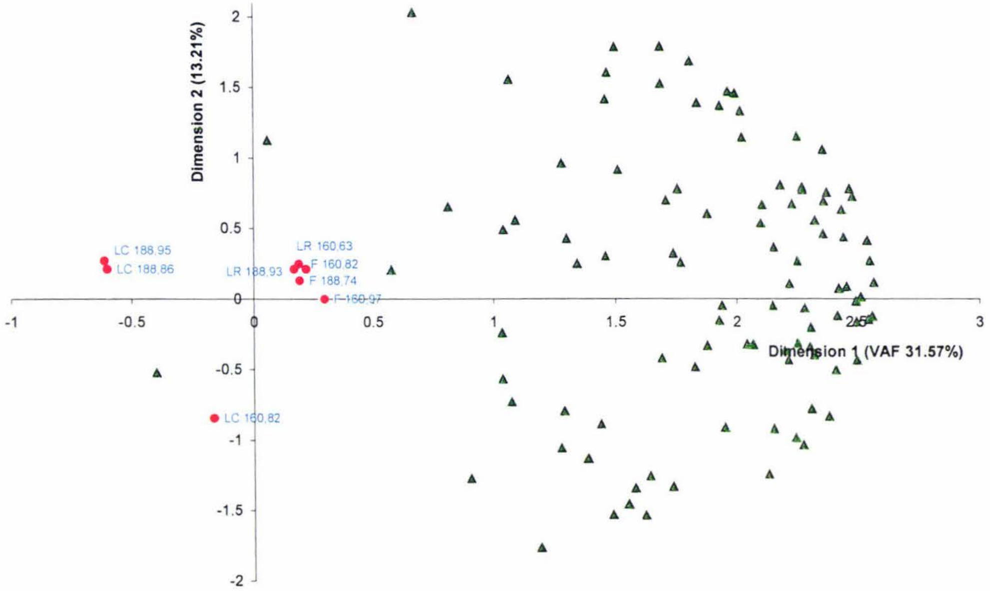


Figure: 4.3a Biplots showing the first two dimensions of consumer preference for firmness

Sample (•) space where LC= loin chop; F = fillet; LR = leg roast; numbers show external and internal temperatures, Consumer preference vectors shown as (▲)

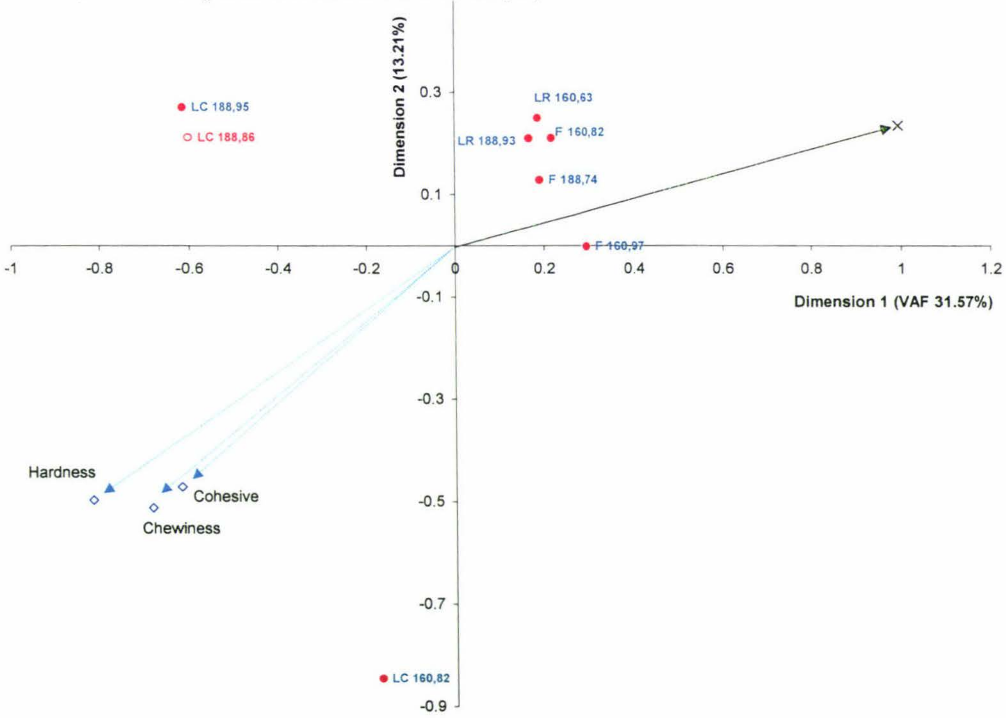


Figure: 4.3b Interpretation of the sample space defined in Figure 4.3a, using sensory data generated by the trained panel

Sample (•) space generated from firmness preference data (where LC= loin chop; F = fillet; LR = leg roast; numbers show external and internal temperatures, direction of liking for total samples shown as →, direction of increase in sensory attributes are shown as →. (o) sample data not used for correlating trained panel data.

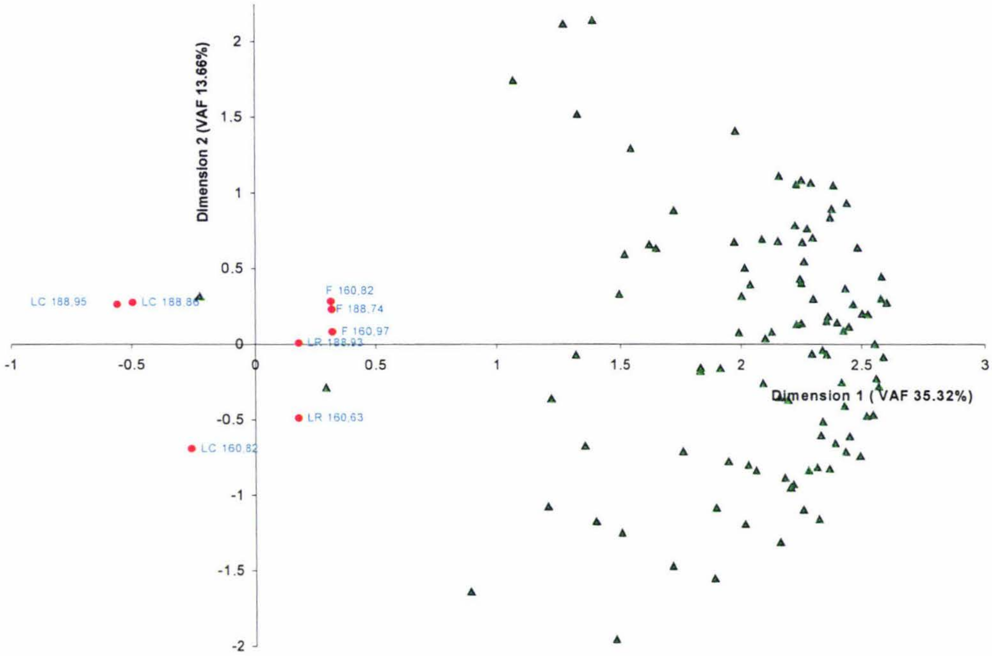


Figure: 4.4a Biplots showing the first two dimensions of consumer preference for juiciness
Sample (•) space where LC= loin chop; F = fillet; LR = leg roast; numbers show external and internal temperatures, Consumer preference vectors shown as (▲)

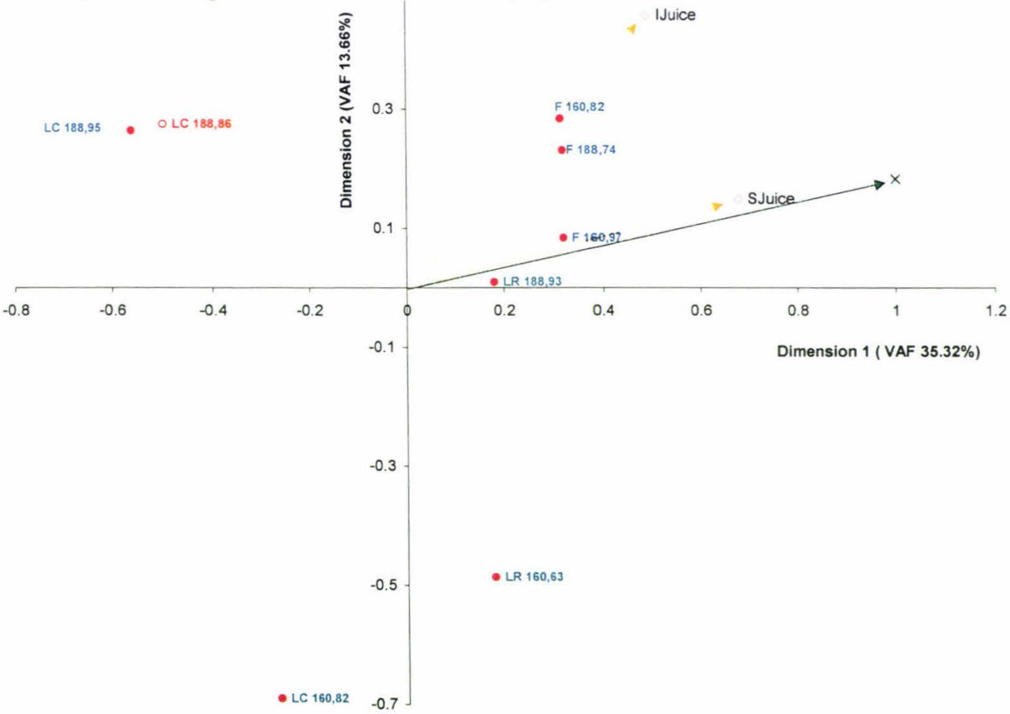


Figure: 4.4b Interpretation of the sample space defined in Figure 4.4a, using sensory data generated by the trained panel
Sample (•) space generated from juiciness preference data (where LC= loin chop; F = fillet; LR = leg roast; numbers show external and internal temperatures, direction of liking for total samples shown as →, direction of increase in sensory attributes are shown as →. (o) sample data not used for correlating trained panel data.

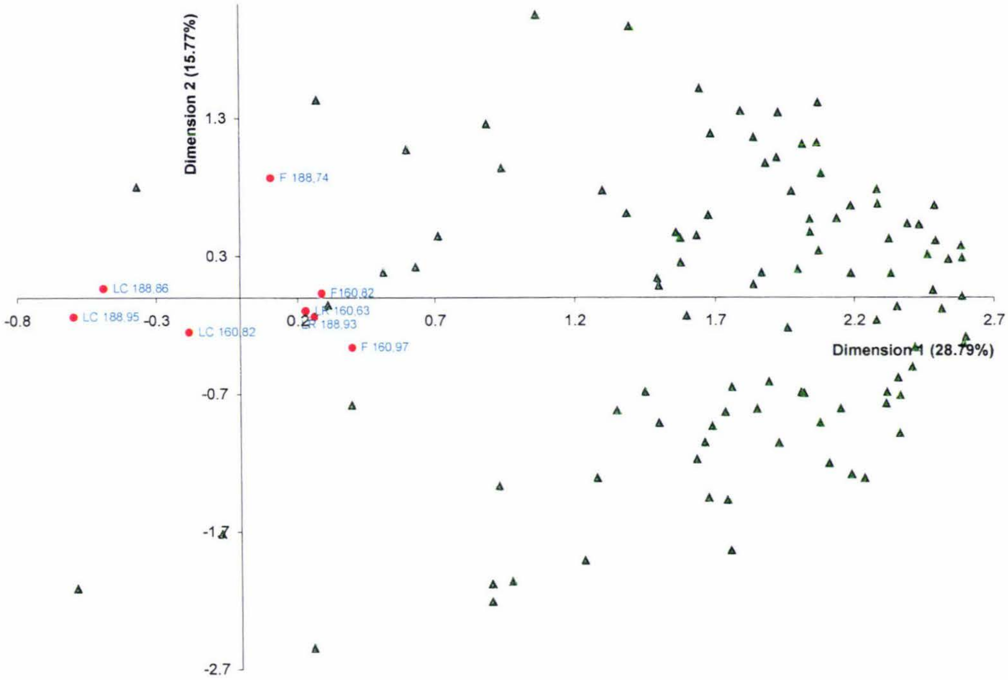


Figure: 4.5a Biplots showing the first two dimensions of consumer preference for flavour
Sample (•) space where LC= loin chop; F = fillet; LR = leg roast; numbers show external and internal temperatures, Consumer preference vectors shown as (▲)

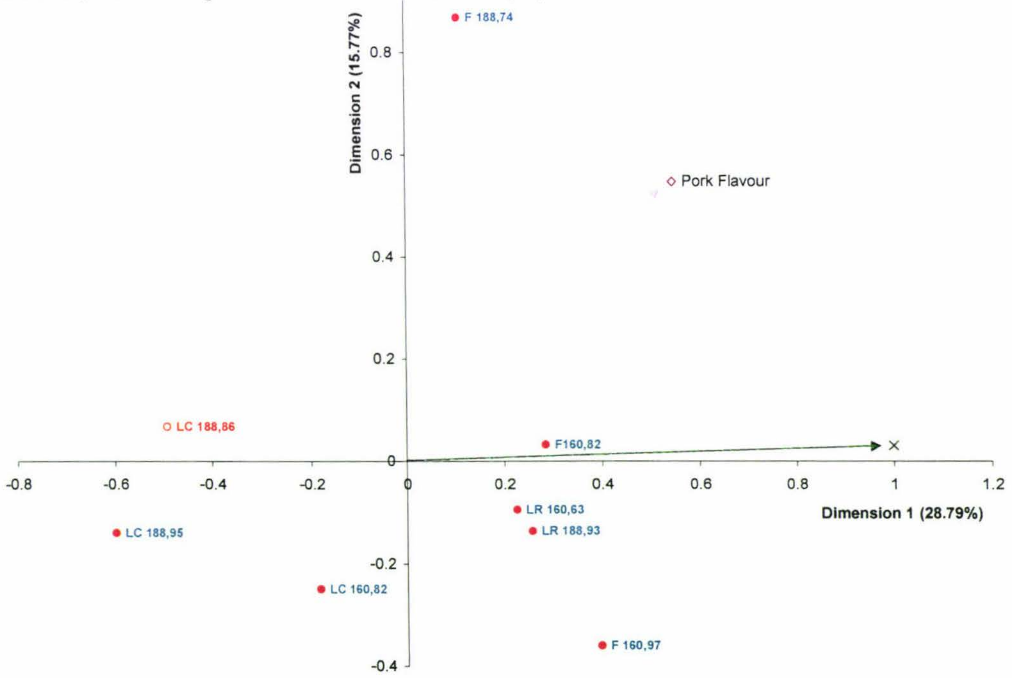


Figure: 4.5b Interpretation of the sample space defined in Figure 4.5a, using sensory data generated by the trained panel.
Sample (•) space generated from flavour preference data (where LC= loin chop; F = fillet; LR = leg roast; numbers show external and internal temperatures, direction of liking for total samples shown as →, direction of increase in sensory attributes are shown as →. (o) sample data not used for correlating trained panel data.

A further understanding of the consumer preferences towards pork can be obtained by analysing the overall liking data.

4.4.2 Consumers' Overall Liking

The means and the standard deviations for the overall liking of the eight pork samples are shown in Table 4.4. There doesn't appear to be a strong relationship between temperature and overall liking as there are combinations of both high and low internal temperatures for similar liking scores. The relationship between cuts is stronger, clearly showing that the fillets and leg roasts are significantly preferred over the chops as the means are higher and the standard deviations are lower.

Table 4.4 Means and standard deviations of overall liking

Sample	External Temperature (°C)	Internal Temperature (°C)	Mean[1,2]	St. Dev
Chop	E^{160}	I^{82}	4.85^{c}	2.21
Chop	E^{188}	I^{86}	3.02^{d}	2.09
Chop	E^{188}	I^{95}	2.82^{d}	2.27
Fillet	E^{188}	I^{74}	6.75^{b}	2.22
Fillet	E^{160}	I^{82}	7.46^{ab}	1.78
Fillet	E^{160}	I^{97}	7.83^{a}	1.91
Leg Roast	E^{160}	I^{63}	7.12^{ab}	1.72
Leg Roast	E^{188}	I^{93}	7.10^{ab}	1.80

[1] Means in the same column with same letter are not significantly different ($p<0.05$)

[2] Unstructured 10cm scale where 0= dislike extremely, 5= neither like nor dislike, and 10= like extremely

4.4.2.1 Internal Preference Mapping

The preference map (Figure 4.6a) produced using the biplot procedure shows that the first two dimensions (principal components) explain 46% of the variation in the overall liking data. Including an extra dimension (Figure: 4.6b) increases the variation accounted for to 59%.

The preference space defined by the first two dimensions show a clear split of samples into two groups with the loin chops placed at the left of the map and the fillets and leg roasts placed at the right of the map. This is also visible in the preference space defined by dimensions one and three. However, the main effect of the third dimension is to increase the separation between samples F188,74 and LR 160,63.

The overall direction of liking as indicated by the consumer vectors is towards the right side of the map along the axis of dimension one. This shows that dimensions two and three have little relationship with the overall liking.

These maps indicate that the fillets and the leg roasts are preferred more than the chops. Furthermore sample F160, 97 is placed furthest to the right side of the map indicating as most liked and sample LC 188, 95 is placed furthest to the left of the map indicating as least liked. Hence the preference mapping analysis clearly complements the mean scores in Table 4.4.

To gain valuable information from Figure 4.6a and 4.6b these maps have to be interpreted. Identifying those sample characteristics that are related to these preference maps does this.

In Figure 4.6a,b consumer scoring (liking) of pork sample attributes are related to the sample map by means of correlation (the mean scores of the attributes are correlated with the sample coordinates for the preference dimensions examined). These attributes rated by consumers are close together indicating positive correlation. All of the attributes have been also rated favourably for the most preferred product. This could be because of a psychological factor called the halo effect that is influencing the sensory perception of these consumers.

As mentioned by Meilgaard et al. (1987) when more than one attribute of a sample is evaluated, the rating will tend to influence each other (halo effect). In this trial consumers were not only asked to rate their overall liking, but also rate the liking of attributes such as juiciness, firmness, flavour and colour. Owing to the halo effect, all attributes of most liked samples have been rated favourably and vise-versa.

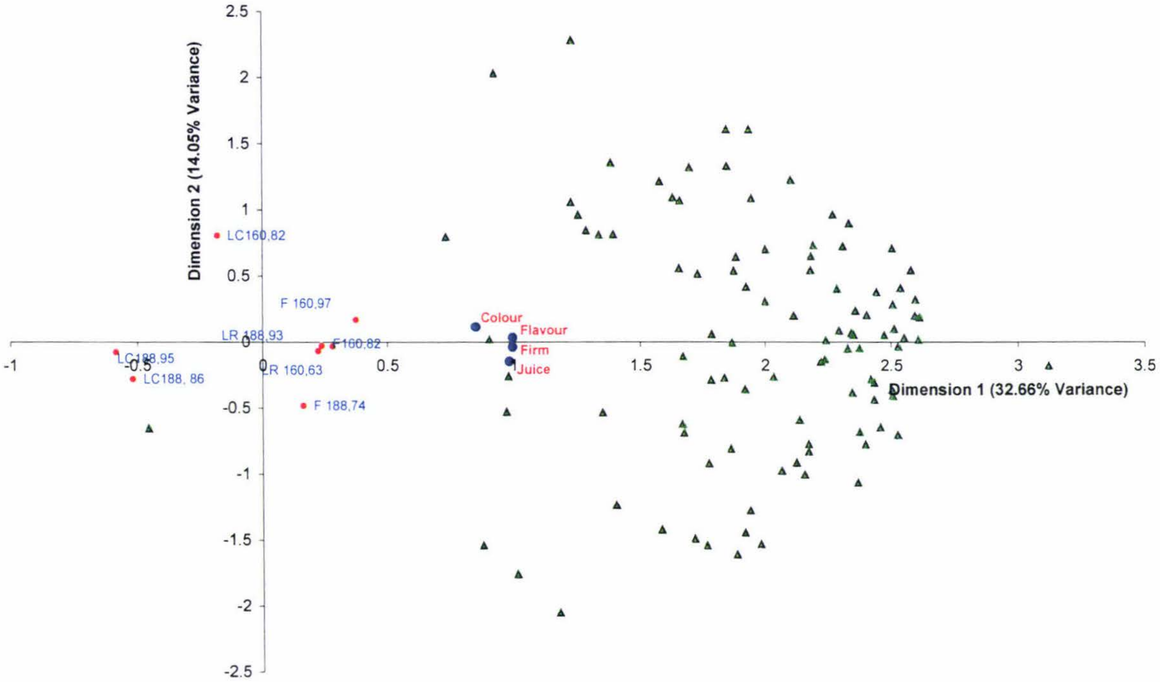


Figure: 4.6a. Internal preference mapping on overall liking data (dimensions 1 and 2)
Sample (•) space where LC= loin chop; F = fillet; LR = leg roast; numbers show external and internal temperatures, consumer preference vectors shown as (▲), consumer rating of sample attributes shown as (•).

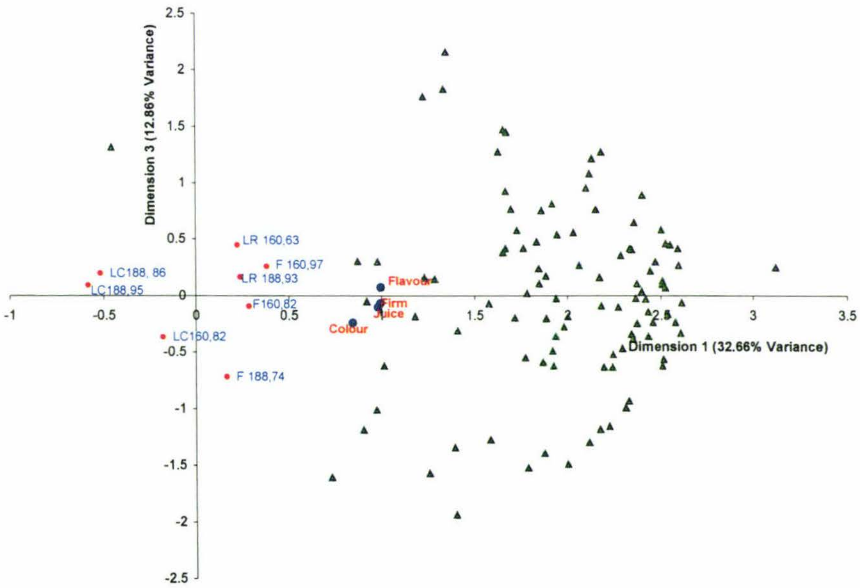


Figure: 4.6b. Internal preference mapping on overall liking data (dimensions 1 and 3)
Sample (•) space where LC= loin chop; F = fillet; LR = leg roast; numbers show external and internal temperatures, consumer preference vectors shown as (▲), consumer rating of sample attributes shown as (•).

A better method of understanding the preference space is to use more precise data obtained from a trained sensory panel, not at all influenced by likes and dislikes (Greenhoff and MacFie, 1994). This is done by correlating the sample means for each attribute (initial juiciness, sustained juiciness, cohesiveness, hardness, chewiness, flavour) obtained from trained panel with the corresponding sample coordinates generated from multivariate analysis (for the preference dimensions examined), and is shown in Figures 4.7a and 4.7b.

It should be taken into consideration that the measured internal temperature for sample LC188, 86 was significantly higher than the target temperature that was specified in the design. As mentioned before the internal temperature of these loin chops was raised to 86°C instead of 70°C. Since the trained panel experiment had been completed prior to this trial it was not possible to gather similar data for this particular temperature combination, so only the data of the remaining seven samples could be used for the correlation. To indicate this discrepancy the symbol for LC 188, 86 has been shown differently in the plots.

To further enhance the interpretation Hunter colour measurements L*, a*, and b* have also been correlated in the map.

Interpretation of the sample space in figure 4.7a indicate that the first preference dimension is related to sensory attributes pork flavour and sustained juiciness on one side against hardness and cohesiveness on the other. This dimension or component mainly depicts the difference between the fillet and loin roast samples, especially F160, 97 and F 160, 82 Vs LC 188, 95. The second dimension separates sample F188,74 from LC 160, 82 and is related to initial juiciness and to a lesser extent with chewiness. The attribute chewiness is associated to both the dimensions.

The overall liking in this map is positively associated with sensory properties such as pork flavour and sustained juiciness and to a lesser extent with initial juiciness, but negatively associated with hardness and cohesiveness, and to a lesser extent with chewiness.

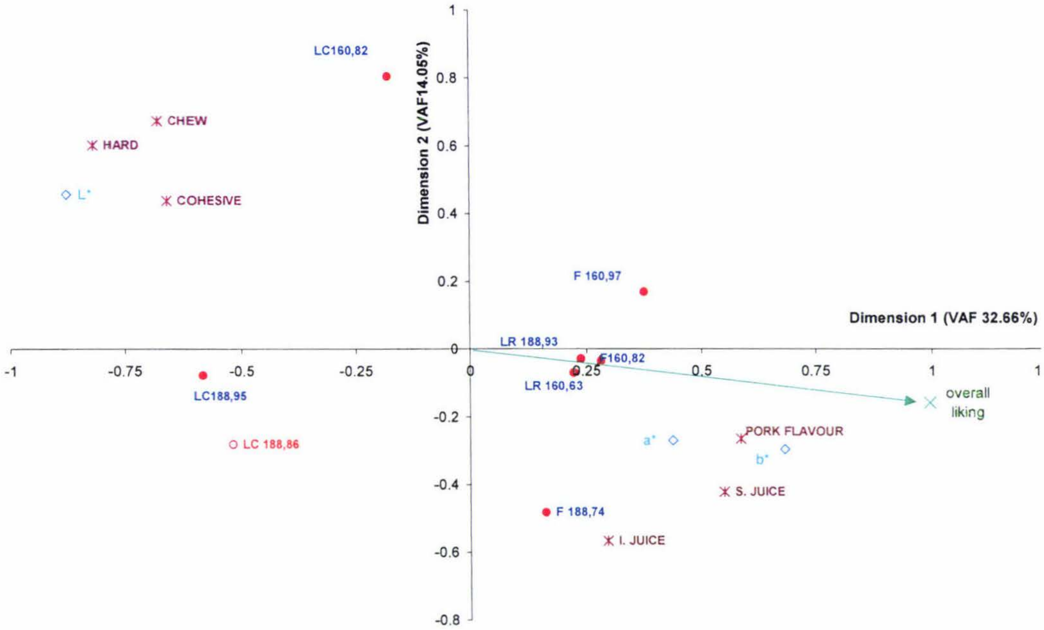


Figure: 4.7a. Interpretation of the sample space defined in Figure 4.6a, using sensory data generated by the trained panel and Hunter colour measurements (dimensions 1 and 2)

Sample (•) space generated from overall liking data (where LC= loin chop; F = fillet; LR = leg roast; numbers show external and internal temperatures, direction of liking for total samples shown as →, sensory attributes are shown as *, and Hunter colour measurements as ◊; Sample (o) not correlated with trained panel data.

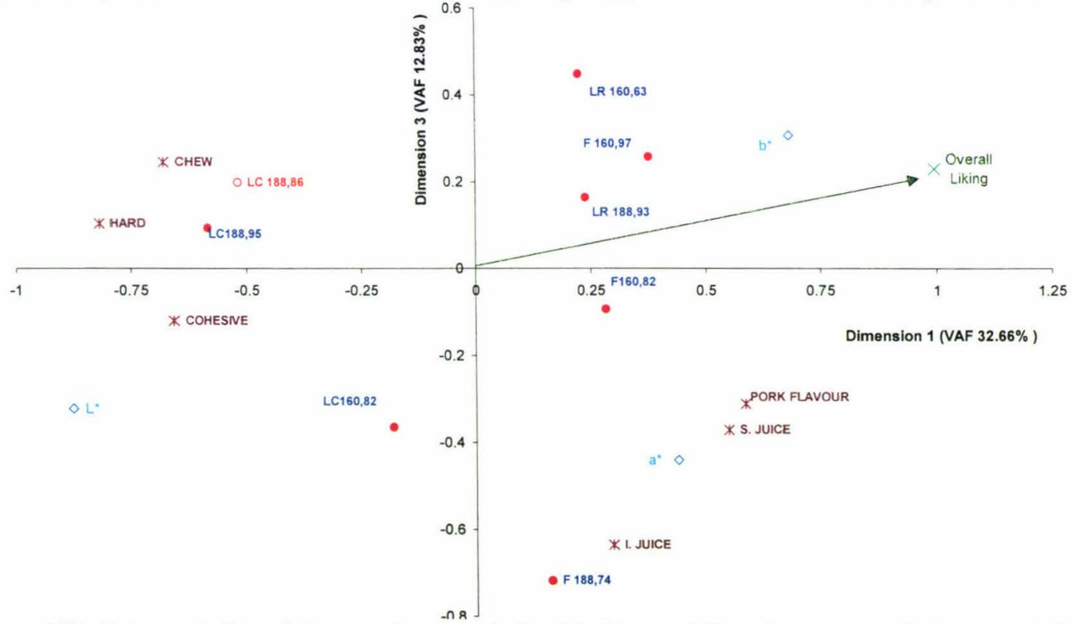


Figure: 4.7b. Interpretation of the sample space defined in Figure 4.6b, using sensory data generated by the trained panel and Hunter colour measurements (dimensions 1 and 3)

Sample (•) space generated from overall liking data (where LC= loin chop; F = fillet; LR = leg roast; numbers show external and internal temperatures, direction of liking for total samples shown as →, sensory attributes are shown as *, and Hunter colour measurements as ◊; Sample (o) not correlated with trained panel data.

Correlations between sensory attributes and overall liking indicated stronger relationships between textural parameters compared to flavour or juiciness. Hardness was significantly negatively correlated ($r=-0.783$, $p< 0.05$) with overall liking. Therefore the textural parameter hardness can be inferred as the most important sensory attribute contributing to preference formation.

A stepwise regression (Minitab) was also done using overall preference data as the response variable and trained panel sensory data (all six attributes) as explanatory variables. The regression equation (a) further emphasises the importance of texture in preference formation. Nevertheless it should be noted that other sensory characteristics influence the texture assessments (Brennan, 1988) and therefore contribute to preference indirectly.

(a) Overall Preference = -7.01 - 4.33 Hardness + 6.1 Chewiness (S = 0.427; R-Sq = 95.4%)

The above equation indicates hardness ($P=0.001$) and chewiness ($P=0.008$)as the best sub set variable to predict overall preference. The low standard deviation (S), and the high R^2 indicates a good fit to means. However hardness and chewiness are highly correlated ($r=0.974$) which is not ideal, thus producing oppositely signed coefficients. Furthermore this analysis was based on average scores where as preference mapping is based on individual consumer scores, not assuming that consumer behaviour is homogenous, thus providing a better understanding of the dynamics involved in preference formation.

Among the Hunter color measurements b* (yellowness) is positively associated with the overall liking and L* (lightness) is negatively associated. colour parameter a* (redness) is weakly correlated ($r=.399$) with the overall liking. These indicate that a more acceptable product in terms of colour tend to be dark and yellowish. However visual measurement of cooked pork colour by trained panelists was not conducted in this experiment. Drawing conclusions based on instrumental measurements of colour alone is dubious because differences identified by these measurements may not be identifiable by human senses. It is also important to investigate the correlations of subjective and objective measurements before arriving at any clear conclusions.

Figure 4.7b depicts similar results to 4.7a, apart from the influence of the third dimension which increasing the separation between samples F188,74 and LR 160,63 mainly due to the differences in initial juiciness.

From these figures it is apparent that sample F160, 97 is most liked because of its intense pork flavour, and sustained juiciness, texture that is soft, and easy to break apart. Sample LC 188, 95 is most disliked because of its lack of pork flavour and sustained juiciness, and hard, cohesive texture.

The lowering of internal temperature for smaller cuts such as pork chops and fillets was recommended in chapter three. Mean scores of consumer overall liking for chops further emphasizes this, i.e. the mean overall liking score (Table 4.4) for chops cooked to an internal temperature of 82°C (LC 160, 82) is significantly ($p<0.05$) higher than chops cooked to 95°C (LC188, 95). However, the mean overall liking scores for fillets do not indicate an increase in liking due to the decrease in internal temperature. In fact it shows an opposite trend where fillet cooked to an internal temperature of 74°C (F188, 74) is significantly less preferred in comparison to fillet cooked to an internal temperature of 97°C (F160, 97). As indicated in chapter three this particular cut shows minimal changes in texture due to temperature (for both IT and ET) differences. Hence the cause for the opposite trend in liking scores is factors other than texture. In this experiment the outer browned surface of the fillet was removed before presentation to the consumers for evaluation. This was mainly done because the meat had to be cut into pieces (20-30g) and consistency in the colour of the surface and flavour (amount of browned surface in a piece influences the flavour) needed to be maintained. Since sample F188, 74 is high in initial juiciness compared to F160, 97 (as evident from chapter three) and the outer browned surface was removed, the surface of the cut meat sample could have appeared moist / watery causing some degree of dislike. Also due to the unfamiliarity of eating samples cooked at 74°C some consumers may have perceived, from the appearance and mouth-feel properties, that the sample was under cooked.

If a lower internal temperature for fillets is to be recommended it is important to inform the consumers about the benefits such as the increase in sustained juiciness and reduction in cooking time. Including the use of lower internal temperatures for cooking fillets in recipes, cook books and restaurants will familiarise consumers with the sensory properties associated and improve the preference rating in due course.

The means and medians of overall liking scores for both the samples LR 160, 63 and LR 188, 93 are the same. The trained panel results in chapter three indicate that an increase of internal temperature for leg roasts reduces the sensory scores for hardness, cohesiveness and sustained juiciness. This means the high values of hardness and cohesiveness for leg roasts cooked to a low internal temperature of 63°C is associated to negative preference and the high sustained juiciness of this sample is associated to positive preference. Similarly, the low values of hardness and cohesiveness for leg roasts cooked to a high internal temperature of 93°C is associated to positive preference and the sustained juiciness of this sample is associated to negative preference. This balance in preference caused by the different sensory attributes at both the internal temperatures explains the similarity in overall liking scores.

4.4.2.1. Consumer Segmentation

Visual inspection of all the maps (biplots) shows no clear consumer groupings or clusters. This indicates a lack of consumer segments based on similarity of preference among the 101 consumers who participated in this test. The next step was to find out if these consumers could be segmented on the basis of some differentiating characteristics obtained from the consumer survey. These characteristics were identified as frequency of pork consumption (question 6), preferred pork cut (question 12), preferred method of cooking (question 14), preferred doneness level (question 16), and reason for preferring the specific doneness level (question 17). The plots for overall liking showing the distribution of consumers based on each characteristic are shown in Appendix 4.3. The final conclusion is that there are no clear segments in the sample group of consumers who participated in this trial based on their preference to roasted pork and the usage information they supplied.

4.5 Results & Discussion – Consumer Survey

The survey results are shown in Appendix 4.4. The demographic information obtained from this survey shows that the 101 consumers participated in this assessment consisted of 54 females and 46 males and 86% of them ate pork at least once a fortnight which matched our selection criteria. The purchase of pork by these consumers was mainly from supermarkets (68%).

The total scores from ranking the three main reasons for eating pork indicate that these consumers eat pork mainly because they like it very much followed by its ease of preparation and its nutritive value. In other words, these frequent eaters of pork simply like the characteristics of this meat, and have developed definite and familiar ways of preparing and cooking the cuts they like. Bennett (1997) reported that many consumers find pork hard to cook, which is an indication that such consumers tend to eat pork less frequently.

Based on the first choice and cumulative scores, roasts were rated as the cut likely to be eaten the most by these consumers. Preference for other cuts in descending order were chops, fillets, steaks, and spare ribs. Even the response to the most eaten cut in the last one year indicated the roasts well ahead in front followed by the chops. Due to the increased influence of other ethnic food preparations (i.e. stir fry), the demand for versatility and quick and easy meal preparations, it was expected that the less traditional cuts such as steaks, dice and strips would be more popular. However, for this group of consumers, the pork roast was still rated the highest.

Roasting was the most used cooking method by these consumers which indicates the reason for selecting roasts as the most preferred and most used cut. Though there was no strong indication of the influence of other ethnic food preparations based on the selection of cuts, the rating of stir-frying as the second most used cooking method shows the influence of Asian cooking. Barbecuing was not highly rated as a cooking method. This was not consistent with the focus group results conducted in Sydney, obtained in stage 1 of this project (Saunders et al, 1999). This may have been due to the fact that both these studies were conducted in different parts of Australia. Also some consumers may have marked roasting and grilling when they actually used a barbecue for cooking.

Thirty percent of these consumers have indicated that they always remove the external fat prior to cooking. This could be mainly due to health reasons. The presence of external fat (before and after cooking) in preference formation was not tested in this trial. This would be worthwhile investigating in future trials.

Doneness level is critical to this project. The preferred doneness level indicated by the consumers and the main reason for selecting that doneness level is shown in Table 4.5. These shows 70 percent (70 consumers) of the consumers prefer the pork cooked to medium or medium to well done state.

Table 4.5 Preferred doneness level and reasons for that preference

Reason for doneness level	Rare	Rare to Medium	Medium	Medium to well done	Well done	No response
Colour	0	0	3	1	1	0
Flavour	0	1	12	11	7	0
Firmness	0	1	4	5	2	0
Juiciness	0	3	14	2	3	1
Safety to eat	0	0	4	11	11	0
Others	0	1	0	0	0	0
No response	0	0	0	3	0	0
Total	0	6	37	33	24	1

The flavour has been indicated to be the main reasons for preferring these doneness levels followed by juiciness and safety to eat. This clearly indicates that consumers prefer the cooked caramalised flavour of pork compared to pork flavour (that is detectable at rare and rare to medium stages) and consumers are also concerned about the juiciness of pork. Though an increase in end point temperature increases the cooked flavour, it decreases juiciness. Therefore while recommending end point temperatures a balance in achieving both of these attributes need to be considered.

The other interesting observation is that nearly 25% of the 101 consumers surveyed are concerned about the safety of eating pork when considering the doneness levels. Eating under cooked pork is thought to cause diseases. The parasite *Trichinella Spiralis* can be acquired from eating under cooked meat. This parasite presents a potential hazard for transmission of diseases to man from pig. This is also the main reason for the advice given in the past, that pig meat should be cooked thoroughly. However it has been reported that Trichinosis occurs world wide except for Australia and many of the Pacific Islands (http://www.informatics.drake.edu/idh/html/chapter/mono/ja001700.htm). Epidemiological data on Trichinellosis published in the International Commission on Trichinellosis web-site supports this claim (http://www.krenet.it/ict/). This information needs to be passed to consumers. Research has shown that the thermal death point of trichinae is between 54.4°C and 60°C (Carlin et al, 1969). Therefore, eating pork cooked above an internal temperature of 60°C is safe and consumers need not over cook pork.

The most common method of determining doneness level, as indicated by these consumers is, by assessing the internal colour of meat (37% of consumers), followed by the way meat cut and the colour of the juices (both accounting for 19% of the consumers). Only 9% of the consumers used cooking time alone. This information is very useful for developing devices that could assist consumers in determining the level of doneness.

These consumers were finally asked what information would help them in cooking pork more successfully. Over two thirds of those who responded (74%) indicated that they would like to see suggestions of cooking methods available for the pork products, while 35% would like recipe suggestions, and 8% an indication of tenderness.

4.6 Conclusions

This research shows the importance of textural attributes in influencing consumer overall liking for cooked pork. Softness (tenderness) is the sensory factor of most importance in driving consumer preferences for pork. This is similar to the results of Diamant et al.

(1976) and Enfalt et al. (1997). Tenderness is also reported to be the most studied meat characteristic with consumers (Chambers & Bowers, 1993). Cooked pork that is primarily soft in texture which is also flavoursome, and juicy (sustained juiciness) is what this segment of Australian consumers like.

Results from chapter three have indicated that the softness of pork is achieved at lower internal temperatures for smaller cuts and at higher internal temperatures for larger cuts. This means the recommended internal temperatures for larger cuts need to be higher than for smaller cuts. Internal temperatures have to be low for smaller cuts, in order to optimise the sensory properties in accordance with the liking of consumers. The stigma that prevails with regard to the safety of pork that is cooked to rare or rare to medium needs to be addressed. These consumers need to be familiarised with the sensory properties associated with pork cooked to lower internal temperatures. Including the use of lower internal temperatures for cooking pork in recipes, cook books and restaurants will enable this and improve their preference rating in due course.

Flavour in pork can be investigated in detail by considering the intensity of pork flavour and cooked flavour. The trained panel scores in chapter three have indicated that pork flavour decreases as the internal temperatures increase. Webb et al. (1961) have stated that cooked flavour of meat is a function of the various tissue components (muscle fibers and connective tissues) that combine and concentrate as time and temperature increase. It has also been reported that the higher perceived flavour of pork roasts during the increase of internal cooking temperature, is attributed to interactions between indigenous carbonyl-amine compounds to form Maillard reaction products at the higher temperature (Bailey, 1983; Mottram, 1992). In cooking, the internal temperature is the main factor controlling the doneness levels. Consumer survey results for the most preferred doneness level indicate a larger percentage preferring the medium and medium to well done doneness levels. The flavour has been indicated to be the main reasons for preferring these doneness levels. This clearly indicates that consumers prefer the cooked caramalised flavour of pork compared to pork flavour, which is high at rare and rare to medium doneness levels. This is further emphasised in the flavour biplots (Figure 4.5a and 4.5b) where the vectors for trained panel rating of pork flavour and the consumer panel rating for flavour likings are apart, showing a lack of correlation.

Although these consumers prefer the flavour of pork cooked to higher internal temperatures, it should be noted that juiciness will inevitably be reduced at these temperatures. As indicated before, a loss of juiciness means a loss in consumer liking. Therefore, the aspect of optimising both these attributes needs to be taken into consideration while recommending end point temperatures.

4.7 Further Considerations & Limitations

In this trial the browned surface of the meat samples was removed and then cut into small pieces (20-30g) prior to serving to the consumers. This was done to standardise all the samples that were served. However this would have altered the flavour and appearance considerably. This is not a normal procedure followed by consumers and hence should be avoided as much as possible in the future. The enjoyment of eating meat starts from the meat on the plate; initially the appearance of the cooked meat, followed by the ease of cutting and picking it up with a fork, the aroma that seeps through the nostrils before putting in the mouth, and finally the sensation in the mouth. When conducting consumer preference testing, consideration should be given to capturing these processes during the evaluation. For example, larger portions of meat could have been served to the consumers so that they would have had the opportunity to go through the process of cutting the meat before eating. This would have given more realistic results. Furthermore, marinades or sauces were not used and the consumers were not aware of the type of cut they were tasting. These factors can influence preference ratings and therefore would be worthwhile investigating in future trials.

CHAPTER 5

Conclusions and Recommendations

The focus of this research was twofold. Primarily, it was to quantify the effects of external (oven) temperature and meat internal (end-point) temperature on pork sensory and physical characteristics during roasting of portion cuts such as chop (loin), fillet, leg, loin, shoulder, and scotch. Secondly, a segment of Australian consumer preferences to selected cuts of pork roasts and cooking conditions were investigated and sensory attributes that are most important for preference formation were identified.

The use of central composite rotatable design and response surface analysis enabled the deduction of important features with regard to the effects of internal temperature and external temperature on pork sensory and physical attributes. The response surface has made it possible to assess the internal and external temperature combination (within the boundaries tested here) that yields desirable levels for the sensory attributes. This information can be communicated to the Australian consumers and the food industry to obtain the required sensory quality during roasting pork.

The effect of internal temperature on sensory and physical characteristics of roasted pork is in general agreement with the results of other workers with few exceptions. However, published information on the use of a range of cuts similar to this research is limited. The overall changes that occur in the sensory properties due to the effect of an increase in internal temperature are:

A. Chop & Fillet Roasts – Decrease in juiciness (initial & sustained) and pork flavour.
B. Leg Roasts – Decrease in sustained juiciness, hardness and cohesiveness.
C. Loin Roasts – Decrease in hardness, cohesiveness and chewiness.
D. Shoulder Roast - Decrease in hardness and cohesiveness.
E. Scotch Roast - Decrease in juiciness (initial & sustained), and cohesiveness.

Similarly changes that occur in evaporation loss (%), drip loss (%) & cooking time (min/kg) due to the effect of an increase in internal temperature are:

A. Chop, Leg and Scotch Roast – Increase in evaporation loss, drip loss & cooking time.
B. Fillet, Loin, Shoulder Roast – Increase in evaporation loss & cooking time.

Some researchers have reported effects of external temperature on sensory attributes, but little effect was observed in this research. The changes that occur in evaporation loss, drip loss & cooking time due to the effect of an increase in external temperature are:

A. Chop, Leg, Scotch Roasts – Increase in evaporation loss, decrease in drip loss and cooking time.
B. Fillet, Loin, Shoulder Roast - Increase in evaporation loss and decrease cooking time.

The attributes not mentioned above under each cut have no significant linear component in their relationship with the relevant temperature.

Recommending cooking conditions that would match the driving forces of consumer preferences will ultimately increase consumer satisfaction. In determining the driving forces the use of consumer preference data is maximised by correlating it with the trained panel data. Hence, the results from the correlation of hedonic and trained panel data (Chapter 4) indicate the importance of textural attributes in influencing consumer overall liking for cooked pork. **Softness (tenderness) is the sensory factor of most importance in driving consumer preferences for pork.** This is in good agreement with the results of other workers. Cooked pork that is primarily soft in texture which is also flavoursome, and juicy (sustained juiciness) is what this segment of Australian consumers like. As mentioned previously (Chapter 4) softness of pork is achieved at lower internal temperatures for smaller cuts and at higher internal temperatures for larger cuts. Increasing internal temperature also significantly increases cooking time. **Therefore, the recommended internal temperatures for smaller cuts should be within the range 68-70°C and for larger cuts within the range of 80-85°C to optimise the sensory properties in accordance with the liking of consumers.** Table 5.1 lists the recommended internal and external temperatures obtained from this research.

Table 5.1 Recommended ET and IT for different cuts

Cut	ET (C°)	IT (C°)
Loin Chop	160 –170	68 - 70
Fillet	160 –170	68 - 70
Leg	180 –190	80 – 85
Loin	180 –190	80 – 85
Shoulder	180 –190	80 – 85
Scotch	160 –170	68 - 70

ET- external temperature; IT- internal temperature

It is recommended that in order to gain maximum benefit from this research, the following aspects be considered.

1. Cooking equipment must be considered when recommending the optimum temperatures. Commercial convection type ovens were used in this study to ensure uniform cooking of the product. However, most domestic type ovens radiate heat from top and bottom, causing large temperature differences in the oven chamber. The sensory and physical changes that occur in pork roasts cooked in these ovens may not follow the same pattern as our research.
2. All cuts were thawed prior to roasting in this trial. Though cooking from frozen takes more time it is worth while investigating the effect of thawing on sensory and physical characteristics of roasted pork.
3. Searing is a cooking technique frequently used by chefs especially for small cuts. It would be very useful to investigate the changes in sensory properties due to searing and if beneficial could be recommended to consumers. Except for Child (1938) no other literature was found comparing seared and un-seared roasting.

4. As mentioned previously, the outer surface of the meat was removed prior to evaluation by the trained sensory panel and consumers. The effect of this on sensory perceptions needs to be established for both the trained and consumer panel.
5. Pork roasts are generally served with an accompanying sauce. The use of marinades in meat is also becoming a common practice among consumers. These sauces and marinades affect the overall sensory experience of the meat. Though we have recommended optimum cooking conditions, the effects of these variables have not been studied and needs to be taken into consideration.
6. In this research, we have identified the sensory attributes of cooked pork roasts that are important for preference formation among this segment of Australian consumers. The sensory (i.e. appearance) and non-sensory characteristics of uncooked meat that contribute to the preference formation and purchasing decision of this segment of Australian consumers are unknown. This aspect needs to be investigated to take maximum use of the outcomes of this research.
7. Consumers who participated in this trial were frequent eaters of pork. Laing and Oram (1999) differentiate responses between frequent and infrequent pork eaters. Therefore, it will be worthwhile doing preference mapping on consumers who are not frequent eaters of pork, as they are a potential target market in order to increase market share.
8. The preference mapping results cannot be generalized for all Australian consumers, since this testing was done only in Brisbane.

REFERENCES

Agerhem, H.; Tornberg, E. (1993). Eating quality of pig meat. Meat Focus International: 159-160.

AMSA. (1978). The guidelines for cookery and sensory evaluation of meat. American Meat Science Association, Chicago.

Arditti, S. (1997). Preference mapping a case study. Food Quality and Preference. 8 (5/6): 323-327.

Arnold, G. M., and Williams A. A. (1986). The use of generalised procrustes techniques in sensory analysis. In Statistical Procedures in Food Research. Ed. Piggott. J. R. Elsevier Applied Science, London, UK. 233-254.

Arteaga, G. E., Li-Chan, E., Vazquez-Arteaga, M. C., and Nakai, S. (1994). Systematic experimental designs for product formula optimisation. Trends in Food Science and Technology. 5: 243-254.

Bailey, M.E. (1983). The Maillard reaction and meat flavour. In The Maillard Reaction in Foods and Nutrition, Waller, G. R. and Feather, M. S (Eds). Proceedings of ACS Symposium Series, American Chemical Society, Washington, DC: 169

Bailey, A. J. (1988). Proceedings of the 34th International Congress in Meat Science and Technology. 152.

Bakanowski, S. M. and Zoller J. M. (1984). Endpoint distributions in microwave and conventionally cooked pork. Food Technology. 38:45

Barnes, J. A., Lewis, J. L. and Buick, D. R. (1996). Composition of new-fashioned pork 1994. Food Australia (Supplement). 48 (2): 3-15

Basker, D. (1988). Assessor Selection: Procedures and results. In Applied Sensory Analysis of Foods, Vol. 1. Ed. Moskowitz, H. 125-143. CRC Press, Boca Raton.

Bayne, B. H., Meyer, B. H. and Cole, J. W. (1969). Response of beef roasts differing in finish, Location and size to two rates of heat application. Journal of Animal Science. 29: 283

Beiken, S. L., Eadie, L. M, Griffiths, I., Jones, P. N. and Harris, P. V. (1991a). Assessment of sensory characteristics of meat patties. Journal of Food Science, 56: 1470-1475.

Beilken, S. L., Eadie, L. M., Griffiths, I., Jones, P. N. and Harris, P. V. (1991). Assessment of the textural quality of meat patties; Correlation of instrumental and sensory attributes. Journal of Food Science. 56: 1465.

Bejerholm, A. C. (1984). Experience in taste testing fresh pork at the Danish Meat Research Institute. Proceedings of the European Meeting of Meat research Workers. 4:18: 196-197

Bendall, J. R. and Swatland, H. J. (1988). A review of the relationships of pH with physical aspects of pork quality. Meat Science. 24:85-126

Bennett Judith. (1997). Final Report- Eating quality assurance for pig meat. Prepared for Pig Research and Development Corporation. Project CON (87/1266). J. M Bennett Consulting Services Pty Ltd.

Boccard, R., Buichter, L., Casteels, M., Cosentino, E., Darnsfield, E., Hood, D. E., Joseph, R. L., MacDougall, D. B., Rhodes, D. N., Schon, I., Tinbergen, B. J., and Touraille, C. (1981). Procedures for measuring meat quality characteristics in beef production experiments. Report of a working group in the commission of the European communities' (CEC) Beef Production Research Programme. Livestock Production Science, 8: 385-397.

Bouton, P. E., Ford, A. L., Harris P. V., and Ratcliff, D. (1975). Objective-subjective assessment of meat tenderness. Journal of Texture Studies. 6 (3): 315-328.

Bowers, J. R. and Goertz, G. C. (1966). Effect of internal temperatures on eating quality of pork chops. 1. Skillet and Oven Braising. Journal of American Dietetics Association. 48: 116

Box, G. E. P., Hunter, W., and Hunter, J. S. (1978). Statistics for Experimenters. John Wiley and Sons, Inc., New York, NY.

Bramblett, V. D., Hostetler, R. L., Vail, G. E. and Draudt, H. N. (1959). Qualities of beef as affected by cooking at very low temperatures for long periods of time. Food Technology. 13: 707

Bramblett, V. D. and Vail, G. E. (1964). Further studies on qualities on beef as affected by cooking at very low temperatures for long periods. Food Technology. 18:123

Bramblett, V. D., Judge, M. D. and Harrington, R. B. (1970). Effect of temperature and cut on quality of pork roast. Journal of American Dietetic Association. 57 (2): 132-135

Brennan, J. G. (1988). In sensory analysis of foods. ed. Piggott. J. R. Elservier Science Publishers. New York.

Brewer, M. S. and McKeith, F. K. (1999). Consumer rated quality characteristics as related to purchase intent of fresh pork. Journal of Food Science. 64 (1):171-174

Callier, P., and Schlich, P. (1995). Preference mapping in progress. Paper #39. Presented at Second Pangborn Sensory Science Symposium. Davis, CA., July 30 – Aug. 3.

Cameron, N. D. and Enser, M. (1991). Fatty acid composition of lipids in *longissimus dorsi* muscle of Duroc and British landrace pigs and its relationship with eating quality. Meat Science. 29: 295-307

Cannon, J. E., Morgan, J. B., Heavner, J., McKeith, F. K., Smith, G. C. and Meeker, D. L. (1995). Pork quality audit: A review of the factors influencing pork quality. Journal of Muscle Foods. 6: 369-402

Carlin, A. F., Cash, D. and Mott, C. (1968). Effect of boning and final internal temperature on quality of fresh hams. Journal of American Dietetics Association. 53: 36

Carroll, J. D. and Chang, J. J. (1970). Analysis of individual differences in multidimensional scaling via an N-way generalisation of "Eckart-Young' decomposition. Psychometrika. 35: 283-319.

Carroll. J. D. (1980). Models and methods for multidimensional analysis of preferential choice (or other dominance) data. In similarity and choice, eds E. D. Lanterman and H Ferger, Hans Huber Pub, Vienna, 234-289.

Chambers, E., and Bowers, J. R. (1993). Consumer perception of sensory qualities in muscle foods. Food Technology. 116-120.

Cheng, C. S. (1976). Biochemical studies of postmortem aging, calcium ion and heating of bovine skeletal muscle. Ph.D. Thesis. Lowa State University, Ames, Lowa.

Cheng, H. W. and Baldwin, R. E. (1985). Quality of pork cooked by Stir-Fry and two Microwave procedures. Journal of Microwave Power. 20 (4): 261-265

Child, A. M. (1938). Recent developments in meat cookery research. Journal of American Dietetics Association. 14: 623

Civille, G. V., and Lawless, H. T. (1986). The importance of language in describing perceptions. Journal of Sensory Studies. 1: 217-236.

Clarke, A. D., Ramsey, C. B., Hornsby, V. E. and Davis, G. W. (1983). Consumer preferences for fat and chop thickness in fresh pork chops. Proc. Recip. Meat Conference. 36: 193

Cover, S. (1937). The effect of temperature and time of cooking on the tenderness of roasts. Bulletin. 542. Texas Agric. Expt. Station, College Station, Texas.

Cover, S. and Hostetler, R. L. (1960). An examination of some theories about beef tenderness by using new methods. Bulletin. 947. Texas Agric. Expt. Station, College Station, Texas.

Cover, S., Ritchey, S. J. and Hostetler, R. L. (1962a). Tenderness of beef II, Juiciness and the softness components of tenderness. Journal of Food Science. 27: 476

Cover, S., Hostetler, R. L. and Ritchey, S. J. (1962b). Tenderness of beef IV. Relations of shear force and fiber extensibility to juiciness and six components of tenderness. Journal of Food Science. 27: 527

Coxon, A. P. M. (1982). Three-way and further extensions of the basic model. In The Users Guide to Multidimensional Scaling. Heinemann Educational Books, London.

Daillant-Spinnier, D. MacFie, H. J. H. Beyts, P. K. and Hedderley. D. (1996). Relationships between perceived sensory properties and major preference directions of 12 varieties of apples from the southern hemisphere. Food Quality and Preference. (7)2: 113-126.

Davey, C. L. and Gilbert, K. V. (1974). Temperature-dependent cooking toughness in beef. Journal of the Science of Food and Agriculture. 25: 931

Davis, G. W., Smith, G. C., Carpenter, Z. L. and Cross H. R. (1975). Relationships of quality indicators to palatability attributes of pork loins. Journal of Animal Science. 41: 1305

DeVol, D. L., McKeith, F. K., Bechtel, P. J., Novakofski. J., Shanks, R. D. and Carr, T. R. (1988). Variation in composition and palatability traits and relationships between muscle characteristics and palatability in random sample of pork carcasses. Journal of Animal Science. 66: 385-395

Diamant, R. and Watts, B. M. (1976). Consumer criteria for pork related to sensory, physical and descriptive attributes. Canadian Institute of Food Science and Technology Journal. 9 (3): 152-154

Dijksterhuis, G. B. (1997). Multivariate Data Analysis in Sensory and Consumer Science. Ed. Dijksterhuis, G. B., Trumbull, Conn. Food and Nutrition Press.

Dobrenow, B. (1990). Studies on DFD and PSE pig meat in Australia- State of Queensland. Fleischwirtschaft . 1: 26-36

Draudt, H. N. (1972). Changes in Meat During Cooking. 25th Ann. Recip. Meat Conf., National Live Stock and Meat Board, Chicago: 243-259

Duizer, L. (1992). An assessment of sensory time-intensity and instrumental methods for bovine muscle tenderness measurements. MSc Thesis. University of Guelph, Canada.

Earthy, P. J., MacFie, H. J. H. and Hedderley, D. (1997). Effect of question order on sensory perception and preference in central location trials. Journal of Sensory Studies. 12: 215.

Ellis, M., Webb, A. J., Avery, P., Smithard, R. and Brown, I. (1990). Sex and feeding level effects on the eating quality of fresh pork. Animal Production. 50: 551

Enfält, A. C., Lundström, K., Hansson, I., Lundeheim, N. and Nyström, P. E. (1997). Effects of outdour rearing and sire breed (Duroc or Yorkshire) on carcass composition and sensory technological meat quality. Meat Science. 45: 1-15

Fishken, D. (1990). Consultant's corner. Sensory quality and the consumer: viewpoints and directions. Journal of Sensory Studies, 5, 203-209.

Fjelkner-Modig, F. (1986). Sensory properties of pork, as influenced by cooking temperature and breed. Journal of Food Quality. 9: 89-105

Flores, M., Armero, E., Aristoy, M. C., Toldra, F. (1999). Sensory characteristics of cooked pork loin as affected by nucleotide content and post-mortem meat quality. Meat Science. 51: 53-59.

Fox, J. D., Wolfram, S. A., Kemp, J. D. and Langlois, B. E. (1980). Physical, chemical , sensory and microbiological properties and shelf life of PSE and normal pork chops. Journal of Food Science. 45: 786

Gaddis, A. M., Hankins, O. G. and Hiner, R. L. (1950). Relationships between the amount and composition of press fluid, palatability, and other factors of meat. Food Technology. 4: 498-503

Gains, N. and Gutteridge, C. (1991) Putting taste on the map. Dairy Industries International. 56 (5), 31-33.

Gardes, N., Burg, P. and Fraile, P. (1995). Influence of three cooking methods on some properties of pork roast. Sciences-des-Aliments. 15 (2): 125-137

GENSTAT 5 COMMITTEE (1993). Genstat 5 Reference Manual. Oxford University Press, London.

Gillette, M. (1984). Application of descriptive analysis. Journal of Food Protection, 47: 403-409.

Giovanni, M., (1983). Response Surface Methodology and product optimisation. Food Technology. 41-45.

Greenhoff, K. and MacFie, H. J. H. (1994) Preferece mapping in practise. In Measurement of Food Preferences, Eds. MacFie, H. J. H and Thomson, D. M. H. 137-166. Blackie Academis and Professional, London.

Hamm, R. (1960). Biochemistry of meat hydration. Advances in Food Research. 10: 355

Hamm, R and Hofmann, K. (1965). Changes in the sulphydryl and disulphide groups in beef muscle proteins during heating. Nature. 207:1269

Hamm, R.(1966). Heating of muscle systems . In Physiology and Biochemistry of Muscle as a Food. (Briskey, E. J., Cassens, R. G. and Trautman J. C eds.) University of Wisconsin Press, Madison: 363

Hamm, R. (1969). Properties of meat proteins. In Proteins as Human Food, Lawrie, R. A (Ed), AVI Publication Co., Westport, Conn: 167-185

Hardy, F.; Noble, I. A. (1945). Comparison of measurement of juiciness in roast pork loin by press-fluid and jury-rating methods. Food Research. 10(2): 160-164

Harmon, C. J., Ramsey, C. B. and Davis, G. W. (1990). Effect of cooking method on consumer acceptance and composition of hot-processed pork loins. Journal of Animal Science. 68: 143-147

Harries, J. M., Rhodes, D. N. and Chrystall, B. B. (1972). Meat texture 1. Subjective assessment of the texture of cooked beef. Journal of Texture Studies . 3: 101-114

Hearne, L. E., Penfield, M. P. and Goertz, G. E. (1978). Heating effects of bovine semitendinosus: Shear force muscle fiber measurements and cooking losses. Journal of Food Science. 43: 10-12

Heldman, D. R. (1975). Heat transfer in meat. 28th Ann. Recip. Meat Conf., American Meat Science Association, Chicago: 314-325

Helgesen, H. Solheim, R. and Naes, T. (1997). Consumer preference mapping of dry fermented lamb sausages. Food Quality and Preference. 8 (2): 97-109.

Hendrix, J., Baldwin, R., Rhodes V. J., Stringer, W. C. and Naumann, H. D. (1963). Consumer acceptance of pork chops. University of Missouri Agriculture Experimental Station Research Bulletin: 834

Heymann, H., Hedrick, H. B., Karrasch, M. A., Eggeman, M. K. and Ellersieck, M. R. (1990). Sensory and chemical characteristics of fresh pork roasts cooked to different endpoint temperatures . Journal of Food Science. 55 (3): 613-616

Hines, R. C., Ramsey, C. B. and Hoes, T. l. (1980). Effects of microwave cooking rate on palatability of pork loin chops. Journal of Animal Science. 50:446

Hovenier, R., Kanis, E. and Verhoeven, J. A. M. (1993). Repeatability of taste panel tenderness scores and their relationships to objective pig meat quality traits. Journal of Animal Science. 71 (8): 2018-2025

Howe, J. L., Gullett, E. A. and Usborne, W. R. (1982). Development of pink colour in cooked pork. Canadian Institute of Food Science and Technology Journal. 15 (1): 19-23

Jellinek Gisela. (1985). Sensory Evaluation of Food Theory and Practice. 156

Jeremiah, L. E. (1982). A review of factors influencing consumption, selection, and acceptability of meat purchases. Journal of Consumer Studies and Home Economics. 6: 137-154.

Johnson, R. (1988). Adaptive perceptual mapping. Applied Marketing Research, 28 (1), 8-11.

Johnson, R. A., and Wichern, D. W. (1992). Applied Multivariate Statistical Analysis, 3rd edition. Prentice-Hall, Englewood Cliffs, NJ.

Jolliffe, I. T. (1986) Principal Component Analysis. Springer-Verlag, New York.

Jones, H. E., Jr., Ramsey, C. B., Hines, R. C., and Hoes, T. L (1980). Low temperature roasting of thawed or frozen pork loins. Journal of Food Science. 45: 178-181

Jowitt, R. (1974). The terminology of food texture. Journal of Texture Studies . 5: 351-358

Jul, M. and Zeuthen. (1981). Quality of pig meat for fresh consumption. Progress in Food and Nutrition Science. 4 (6): 13-63

Kohli, C.S., and Leuthesser, L. (1993). Product Positioning: a comparison of perceptual mapping techniques. Journal of Product and Brand Management, 2, 10-19.

Kuhfeld, W. F. (1993). Graphical methods for marketing research. In Marketing research Methods in the SAS System: A Collection of papers and handouts. SAS Institute, Cary. NC.

Laing, D. G., and Oram, N. (1999). Sensory and non-sensory factors that affect pigmeat consumption. Project 261139 for the Pig Reseach and Development Corporation. Centre for Advanced Food Research, University of Western Sydney, NSW.

Landmann, W. A. and Batzer, O. F., (1966). Influence of processing procedures on the chemistry of meat flavours. Journal of Agriculture and Food Chemistry. 14: 210-214

Larson, E. M., Holm, E. T., Marchello, M. J. and Slanger, W. D. (1992). Physical and sensory characteristics of fresh pork leg roasts cooked at low temperatures. Journal of Food Science. 57 (6): 1300-1303

Lawless, H. T., and Heymann, H. (1998). In Sensory Evaluation of Foods, Principles and Practices. 585-620. Chapman 7 Hall, International Thomson Publishing.

Lawrie, R. A. (1966). Meat Science, Pergamon Press, Oxford, England: 305

Lawrie, R. A. (1998). Meat Science, WoodHead Publishing Limited, Cambridge, England: 212-254

Leander, R. C., Hedrick, H. B., Brown, M. F. and White, J. A. (1980). Comparison of structural changes in Bovine longissimus and semitendinosus muscles during cooking. Journal of Food Science. 45: 1-6

MacDougall, D. B. (1986). The chemisty of colour and appearance. Food Chemistry. 21: 283.

MacFie, H. J. H., and Thomson, D. M. H. (1983). Multidimensional scaling methods. In Sensory Analysis of Foods, Ed. Piggot, J. R. Elsevier Applied Science, London. 351-375.

MacFie, H. J. H., and Thomson, D. M. H. (1988). Preference mapping and multidimensional scaling methods. In Sensory Analysis of Foods, Ed. Piggot, J. R. Elsevier Applied Science, London.

MacFie, H. J. H, Bratchell, N., Greenhoff, K. and Vallis, L. V. (1989) Designs to balance the effect of order of presentation and first-order carry over effects in hall tests. Journal of Sensory Studies 4, 129-148.

MacFie, H. J. H., and Hedderley, D. (1993). Current practice in relating sensory perception to instrumental measurements. Food Quality and Preference. 4. 41-49.

Marketo, C. G., Cooper, T., Petty, M. F., and Scriven, F. M. (1994). The reliability of MDPREF to show individual preference, Journal of Sensory Studies. 9. 337-350.

McEwan, J. A., (1996). Preference mapping for product optimisation, In Multivariate Analysis of Data in Sensory Science, Eds. Naes. T. and Risvik, E., 71-102. Elesvier Science Publication.

Meilgaard, M., Civille, G. V. and Carr, B. T. (1987). Sensory Evaluation Techniques . Volume 1: 7

Meilgaard, M., Civille, G. V., Carr, B. T. (1999). In Sensory Evaluation Techniques. CRC Press. Boca Raton, Fla.

Mottram, D. A. and Edwards, R. A. (1983). The role of triglycerides and phospholipids in the aroma of cooked beef. Journal of the Science of Food and Agriculture, 34: 517-522.

Mottram, D. S. (1992). Meat flavour. Meat Focus International. 1. 87-93

Munoz, A. M. and Chambers, E. (1993). Relating sensory measurements to consumer acceptance of meat products. Food Technology, 128-134.

Murray, A. C., and Martin, A. H. (1980). Effects of muscle fibre angle on Warner-Bratzler shear angles. Journal of Sensory Studies, 1: 55-83.

National Live Stock and Meat Board. (1991). The Meat Board's Lessons on Meat: 94-117

Noble, I. and Hardy, F. (1945). Effect of storage temperature and time upon the quality of pork preserved by freezing. Food Research. 10: 165

Nute, G. R., MacFie, H. J. H. and Greenhoff, K. (1988) Practical application of preference mapping. In Food Acceptability, ed. Thomson D. M. H. Elsevier Applied Science, London.

O' Mahony, M. (1979). Psycophysical aspects of sensory analysis of dairy products: a critique. Journal of Dairy Science. 62. 1954.

Patterson, J. L. (1975). In Meat, Coles, D. J. A. and Lawrie, R. A. (Eds), Butterworths, London: 471

Paul, P. C. (1963). Influence of methods of cooking on meat tenderness. Proc. Meat Tenderness Symposium, Campbell Soup Co., Camden, N. J: 225-241

Paul, P. C. and Palmer, H. H. (1972). In Food Theory and Application, John Wiley & Sons, New York

Pearson, A. M., Harrington, G., West, R. G. and Spooner, M. (1962). The browning produced by heating fresh pork. 1. The relation of browning intensity to chemical constituents and pH. Journal of Food Science. 27: 177

Penfield, M. P. and Meyer, B. H. (1975). Changes in tenderness and collagen of beef semitendinosus muscle heated at two rates. Journal of Food Science. 40:150

Pengilly, C. I. and Harrison, D. L. (1966). Effect of heat treatment on the acceptability of pork. Food Technology. 330-333

Popper, R. D., and Heymann, H. (1996). Multidimensional scaling of sensory data. In Multivariate Analysis of Data in Sensory Science, Eds. Naes. T. and Risvik, E., 159-184. Elesvier Science Publication.

Poste, L. M., Butler, G., Mackie, D., Agar, V. E., Thomson, B. K., Cliplef, R. L., and McKay, R. M. (1993). Correlations of sensory and instrumental meat tenderness values as affected by sampling techniques. Food Quality and Preference, 4: 207-214.

Powers, J. J. (1984). Current practises and application of descriptive methods. In Sensory Analysis of Foods. Ed. Piggot, J. R. Elsevier Science Publishers. New York.

Prusa, K. J. and Hughes, K. V. (1986). Cholesterol and selected attributes of pork tenderloin steaks heated by Conventional, Convection, and Microwave Ovens to two internal endpoint temperatures. Journal of Food Science. 51: 1139-1140

Reitmeier, C. A. and Prusa, K. J. (1987). Cholesterol content and sensory analysis of ground pork as influenced by fat level and heating. Journal of Food Science. 52 (4): 916-918

Rhodes, D. N. (1970). Meat quality, Influence of fatness of pigs on the eating quality of pork. Journal of Science in Food and Agriculture. 21: 572

Ritchey, S. J. and Hostetler, R. L. (1964). Relationships of free and bound water to subjective scores for juiciness and softness and to changes in weight and dimensions of steaks from two beef muscles during cooking. Journal of Food Science. 29: 413

Ritchey, S. J. and Hostetler, R. L. (1965). The effects of small temperature changes on two beef muscles as determined by panel scores and shear force values. Food Technology. 19: 93

Roskham, E. E. (1979). The nature of data: Interpretation and representation: An Introduction to the theory of data. In Geometric Representation of Relational Data, Eds. Lingoes, J. C., Roskham, E. E., and Borg, I. 149-235, Mathesis Press, MI.

Saffle, R. L. and Bratzler, L. J. (1959). The effect of fatness on some processing and palatability characteristics of pork carcasses. Food Technology. 13: 236

Santorius, M. J. and Child, A. M. (1938). Problems in meat research. Food Research. 3: 627

Saunders, A., Pound, C., Duizer, L., Cumarasamy, S., Hutchinson, F. (1998). Optimisation of Cooking Procedures for Pork (UNZ 4/ 1386). Second Progress Milestone.

Schiffman, S. S., Reynolds, M. L. and Young, F. W. (1981). Introduction to multidimensional scaling. Academic Press, New York.

Schlich, P. (1995). Preference Mapping: Relating consumer preferences to sensory or instrumental measurements. In Bioflavour '95. Analysis/ Precursor Studies/ Biotechnology, Eds Etievant, P. and Schreier, P. France:INRA Editions.

Seideman, S. C. and Durland, P. R. (1984). The effect of cookery on muscle proteins and meat palatability: A review. Journal of Food Quality . 6: 291

Shocker, A. D., and Srinivasan, V. (1979). Multi-Attribute approaches for product concept evaluation and generation: a critical review. Journal of Marketing Research, 16, 159-180.

Sidel, J.L. and Stone, H. (1985). Sensory Evaluation Practices. Academic Press, New York.

Sidel, J.L. and Stone, H. (1993). The role of sensory evaluation in the food industry. Food Quality and Preference, 4, 65-73.

Siemens, A. L., Heymann, H., Hedrick, H. B., Karrasch, M. A., Ellersieck, M. and Eggeman, M. K. (1990). Effects of external fat cover, bone removal and end point cooking temperature on sensory attributes and composition of pork center loin chops and roasts. Journal of sensory Studies. 4: 179-188

Siemers, L. L. and Hanning, F. (1953). A study on certain factors influencing juiciness. Food Research. 18: 113-120

Simmons, S. L., Carr, T. R. and McKeith, F. K. (1985). Effects of internal temperature and thickness on palatability of pork loin chops. Journal of Food Science. 50: 313-315

Slusar, M. and McDonald, M.(1973). Preference for pork roasted to two internal temperatures. Journal of Canadian Dietetics Association. 34: 19

Smith, J. M. and LeBlanc, D. I. (1990). Evaluation of low temperature meat cooker for the home. Canadian Institute of Food Science and Technology Journal. 23 (4/5): 207-211

Steenkamp, J. E. B. M and van Trijp, J. C. M. (1988). Kwaliteitsbeoordeling van vers vlees door consumenten. Symposium vleeskwaliteit

Stollznow, M. and Stollznow, N. (1997). Pork usage and attitudes study-summary report, prepared for Australian Pork Corporation and The Pig Research and Development Corporation.

Szczesniak, A. S. and Kleyn, D. H. (1963). Consumer awareness of texture and other food attributes. Food Technology. 17: 74-77

Tappel, A. L. (1957). Reflectance spectral studies of the hematin pigments of cooked beef. Food Research. 22: 404

Topel, D. G., Miller, J. A., Berger, P. J., Rust, R. E., Parrish, F. C., Jr. and Ono, K. (1976). Palatability and visual acceptance of dark normal and pale coloured procine *m. longissimus*. Journal of Food Science. 41: 628

Toscas, P. J., Shaw, F. D., Beiken, S. L. (1999). Partial least squares regression for the analysis of instrument measurements and sensory meat quality data. Meat Science. 52: 173-178.

Tucker, L. R. (1960). Intra-individual and Inter-individual multidimensionality. In Psychological Scaling: Theory and Applications.Eds. Gulliksen, H. and Messick, S. 155-167, John Wiley & Sons, New York.

Tunaley, A., Thomson, D. M. H., and McEvan, J. A. (1988). An investigation of the relationship between preference and the sensory characteristics of nine sweetners. In Food Acceptability, ed. Thomson D. M. H. Elsevier Applied Science, London.

Van Oeckel, M.J., Warnants, N. and Boucque, Ch. V.(1999). Pork tenderness estimation by taste panel, Warner-Bratzler shear force and on-line methods. Meat Science. 53: 259-267

Van Trijp, H. C. M. and Schifferstein, N. J. (1995). Sensory analysis in marketing practice: Comparison and Integration. Journal of Sensory Studies, 10. 127-147.

Vieira R Ernest. (1996). Equipment Used in Food Preparation, In Elementary Food Science, Chapman and Hall New York: 352-357

Visser, R. Y., Harrison, D. L., Goertz, G. E., Bunyan, M., Skelton, M. N. And Macintosh, D. L. (1960). The effect of degree of doneness on the tenderness and juiciness of beef cooked in the oven and in deep fat. Food Technology. 14: 193

Wachholz, D., Kauffman, R. G., Henderson. D. and Lochner, J. V. (1978). Consumer discrimination of pork colour at the market place. Journal of Food Science. 43: 1150

Warkup, C. C., Dilworth, A.W., Kempster, A.J and Wood, J. D. (1990). The effects of sire type, company source, feeding regimen and sex on eating quality of pig meat. Animal Production. 50: 550

Warner, R. D., Kauffman, R. G. and Russell, R. L. (1993). Quality Attributes of Major Procine Muscles: A Comparison with the Longissimus Lumborum . Meat Science. 33: 359-372

Webb, N. L., Webb, N. B., Cedarquist, D. and Bratzler, L. J. (1961). The effect of internal temperature and time of cooking on the palatability of pork loin roasts. Food Technology. 371-373

Weir, C. E. (1960). The Science of Meat and Meat Products (Ed. American Meat Institute Foundation), Reinhold Publishing Co, New York: 212.

Weir, C. E., Slover, A., Pohl, C. and Wilson, G. D. (1962). Effect of cooking procedures on the composition and organoleptic properties of pork chops. Food Technology. 133-136

Weir, C. E., Pohl, C., Auerbach, E. and Wilson, G. D. (1963). The effect of cooking conditions upon the yeild and palatability of pork loin roasts. Food Technology. 1567-1568

Wood, J. D., Dransfield, E. and Rhodes, D. N. (1979). The influence of breed on the carcass and eating quality of pork. Journal of Science Food and Agriculture. 30: 493

Wood, J. D. (1993). Consequences of changes in carcass composition on meat quality. In Recent Developments in Pig Nutrition 2, Cole, D. J .A., Haresign, W. and Garnsworthy, P. C. (Eds), Nottingham University Press, Nottingham, UK: 20-29

Wood, J. D., Nute, G. R., Fursey, G. A. J. and Cuthbertson. A. (1995). The effect of cooking conditions on the eating quality of pork. Meat Science. 40: 127-135

Wood, J. D., Brown, S. N., Nute, G. R., Whittington, F. M., Perry, A. M., Johnson, S. P., Enser, M., (1996). Effects of breed, feed level and conditioning time on the tenderness of pork. Meat Science. 44: 105-112

Zondagh, I. B., Holmes, Z. A., Rowe, K. and Schrumpf, D. E. (1986). Prediction of pork and lamb Quality Characteristics. Journal of Food Science. 51: 40-46

APPENDICES

Appendix 3.1 Product Attitude Survey Form

Sensory Evaluation Product Attitude Survey

Please complete this questionnaire. All Information will be maintained confidential.

Please Print

HISTORY:

Name:	Date:
Address:	
Phone: (Home)	Phone: (Business)
Age (Tick one): [15-19] [20-29] [30-39] [40-49] [50-59] [over 59]	
Gender:	Occupation:

Have you ever been or currently are part of a sensory panel ? If yes, where and when____

TIME:

1. Are there any weekdays, (Monday-Friday), that you will not be available on a regular basis? If yes please state days and time.

   ____

2. How many weeks vacation do you plan to take between 11th January – 30th September 1999? Please state the period. ______________________________

3. What time(s) of the day is(are) most convenient for you to attend panels.? Please specify.____

   ____

HEALTH:

1. Do you have any of the following?
   Dentures __________
   Diabetes __________
   Oral Disease __________
   Hypoglycemia __________
   Hypertension __________

2. Do you take any medications which effect your senses, especially taste and smell?
   ____

3. Please indicate which, if any, of the following foods disagree with you. (allergy, Discomfort, ect)
   Cheese (specify)________________
   Chocolate ______________________
   Poultry ________________________
   Fruits (specify) _________________
   Meats (specify) _________________
   Soy _____________________
   Milk _____________________
   Seafood ___________________
   Eggs ______________________
   Vegetables (specify)_________
   Spices (specify) _____________
   Others (specify) ____________

4. Are you currently on a special diet? If yes explain.
   ____

5. What is (are) your favourite food (s)?
   ____

6. What foods do you not like to eat?
   ____

Thank you

Appendix 3.2 Pork Sensory Evaluation Training

Protocols followed during tasting of samples.

- Molars were used.
- Samples were placed so that the muscle fibres were parallel to the molars.
- The dominant side was used during chewing.
- Toothpicks were used to clean stuck residues between the molars.
- Unsalted water crackers were consumed and mouths rinsed with water between samples.
- All samples tested were swallowed.
- A chew rate of one chew per second was maintained.

Details of the training regime

Note that all of the training sessions were conducted in the air-conditioned room (20°C) where the actual testing was carried out.

Day 1

- Panellists were informed of the protocols to be followed, as outlined in the previous section.
- Panellists were provided with three samples of pork derived from whole fillets roasted at 160°C to two end-point temperatures (two samples of the 73°C material used):

S1. 73°C

S2. 95°C

- Panellists were asked to taste the samples and write down the differences between them. The panellists were required to work on their own. They were then asked to read out the differences they noticed.
- The term '*product attributes*' was introduced by listing the differences noticed. At this point in time, a group discussion was encouraged so that the panellists could identify other differences they had not noticed themselves.

- The training staff introduced a list of product attributes.
- The attributes were defined and compared with the list obtained from the panellists.
- Any new attributes the panellists found were added to the list.
- Redundant and ambiguous terms were identified and eliminated.
- Definitions for the attributes were discussed.

Juiciness introduced

- Evaluation of juiciness (initial and sustained) was discussed in detail as a product attribute, using pork fillets roasted at 160°C to the following four end-point temperatures:

S3. 73°C.

S4. 80°C.

S5. 87°C.

S6. 95°C.

- Panellists were then asked to rank the above four samples.
- The ranking test was repeated with samples S3 to S5.
- Measurement of the intensity of juiciness present in a sample was discussed, along with the use of a ten-point line scale.
- The two end descriptors (Not juicy...Very juicy) used on the scale were discussed, along with references for each descriptor.

Day 2

- Juiciness, the use of the line scale, descriptors, and the references were reviewed.
- The line scale evaluation of juiciness (initial and sustained) was performed on samples S3 to S6.
- All results were compared on the whiteboard and discussed.
- The above test was repeated, with the introduction of one replicate.
- All results were compared on the whiteboard and discussed.

Hardness introduced

- The evaluation of hardness was discussed in detail, by providing samples S7 and S9 from below.
- The following three samples were then provided for ranking of hardness (all oven roasted at 160°C):

S7. Whole fillet to 75°C internal temperature.

S8. Topside roast to 75°C internal temperature.

S9. Shoulder roast to 75°C internal temperature.

- The above ranking test was repeated.
- The measurement of the intensity of hardness present in a sample and the use of a ten-point scale were discussed.
- The two end descriptors (soft...hard) used for the scale were discussed, along with references for each descriptor.

Day 3

- Hardness was reviewed and the references revisited.
- The line scale evaluation of hardness was carried out with the following four samples (all oven roasted at 160°C):

S10. Whole fillet to 80°C internal temperature.

S11. Topside roast to 80°C internal temperature.

S12. Topside roast to 90°C internal temperature.

S13. Hock to 80°C internal temperature.

- All results were compared on the whiteboard and discussed.
- The same test was repeated with samples S10, S11 and S13, along with a replicate of sample S10.
- All results were compared on the whiteboard and discussed.
- Juiciness was reviewed and the references revisited.
- The line scale evaluation of juiciness (initial and sustained) and hardness was carried out using samples S10 to S13.
- All results were compared on the whiteboard and discussed.

Day 4

Cohesiveness introduced

- The evaluation of cohesiveness was discussed in detail, providing samples S14 and S15 from below.
- The following four samples were then provided for ranking of cohesiveness (all oven roasted at 160°C):

S14. Whole fillet to 75°C internal temperature.

S15. Whole fillet to 80°C internal temperature.

S16. Rump roast to 75°C internal temperature.

S17. Shoulder roast to 75°C internal temperature.

- The measurement of the intensity of cohesiveness present in a sample and the use of a ten-point scale were discussed.
- The two end descriptors (falls apart....stays together) used for the scale were discussed, along with references for each descriptor.
- The line scale evaluation of cohesiveness was carried out using samples S14 to S17.
- All results were compared on the whiteboard and discussed.
- The line scale evaluation of juiciness (initial and sustained), hardness, and cohesiveness was carried out using duplicate samples of S15 and S16.
- All results were compared on the whiteboard and discussed.

Day 5

- Juiciness (initial and sustained), hardness and cohesiveness were reviewed.
- The line scale evaluation of four samples (S14 to S17) was performed for juiciness (initial and sustained), hardness, and cohesiveness.

Chewiness (number of chews) introduced

- The evaluation of chewiness (the number of chews) was discussed in detail providing samples S18 and S21 from below.
- The following four samples were then provided for ranking of the number of chews (all oven roasted at 160°C):

S18. Loin roast to 65°C end point temperature.

S19. Loin roast to 77°C end point temperature.

S20. Loin roast to 81°C end point temperature.

S21. Loin roast to 95°C end point temperature.

- The test was repeated.
- The measurement of the chewiness of a sample and the use of a ten-point scale were discussed.
- The two end descriptors (not chewy...very chewy) used for the scale were discussed, along with references for each descriptor.
- The line scale evaluation of chewiness was carried out using samples S18 to S21.
- All results were compared on the whiteboard and discussed.
- Juiciness (initial and sustained), hardness, and cohesiveness were reviewed.

Day 6

- Juiciness (initial and sustained), hardness, cohesiveness, and chewiness were reviewed.
- The line scale evaluation of four samples (S18 to S21) for juiciness (initial and sustained), hardness, cohesiveness, and chewiness was carried out.

Pork flavour introduced

- The evaluation of pork flavour was discussed by providing samples S18 and S21.
- Samples S18 to S21 were then provided for ranking of pork flavour.
- The above test was repeated.
- All results were compared on the whiteboard and discussed.
- The measurement of pork flavour present in a sample and the use of a ten-point scale were discussed.
- The two end descriptors (no pork flavour...strong pork flavour) used for the scale were discussed. It was decided to use a whole fillet oven roasted (at 160°C) to 65°C internal temperature as the reference, and this was anchored according to panel agreement.
- The line scale evaluation of pork flavour was carried out using samples S18 to S21.
- All results were compared on the whiteboard and discussed.
- The above test was repeated.
- Juiciness (initial and sustained), hardness, cohesiveness, chewiness and pork flavour were reviewed.

- The sequence of testing for the above six attributes was discussed.
- The line scale evaluation of juiciness (initial and sustained), hardness, cohesiveness, chewiness, and pork flavour was carried out using the following four samples (all oven roasted at 160°C):

S22. Loin roast to 73°C end point temperature.
S23. Loin roast to 77°C end point temperature.
S24. Loin roast to 81°C end point temperature.
S25. Loin roast to 85°C end point temperature.

Days 7 to 10

- Line scale evaluations of samples for juiciness (initial and sustained), hardness, cohesiveness, chewiness, and pork flavour were carried out using different combinations of the following six samples (all oven roasted at 160°C). Three samples were from the same cut of meat (fillets) cooked at different internal temperatures and the other two samples were replicates from another cut of meat (rump, shoulder, loin).

S26. Whole fillet to 65°C end point temperature.
S27. Whole fillet to 75°C end point temperature.
S28. Whole fillet to 90°C end point temperature.
S29. Rump roast to 85°C end point temperature.
S30. Shoulder roast to 85°C end point temperature.
S31. Loin roast to 85°C end point temperature.

- The results from each day were analysed and discussed at the start of the next day. People having problems with a particular parameter were given individual tuition, using appropriate samples and references.

Appendix 3.3 Sample of the Sensory Evaluation Sheet

Name:	**Date:**	**Sample #:**
		Tray #:

Initial Juiciness

☐

Toast	**Celery**	**Apple**
0	6.5	**10**
Not juicy		**Very juicy**

Hardness

☐

	Cream cheese	*Olives*	*Pepperoni*	
0	1	5.5	8.5	**10**
Soft				**Hard**

Cohesiveness

☐

	Rice wafers	*Jelly beans*	*Soft jubes*	
0	0.5	5.5	9	**10**
Falls apart				**Stays together**

PORK flavour

☐

	Pork cube	
0	8	**10**
No PORK flavour		**Strong PORK flavour**

Sustained Juiciness

☐

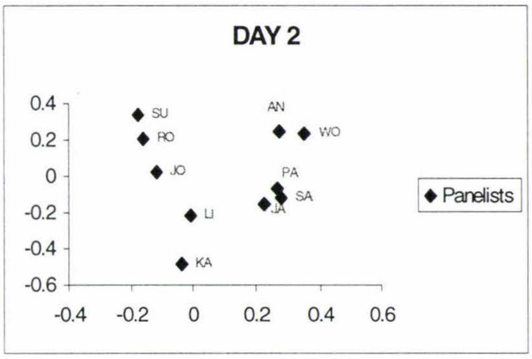
	Tuna	*Carrot*	
0	1.5	6.5	**10**
Not juicy			**Very juicy**

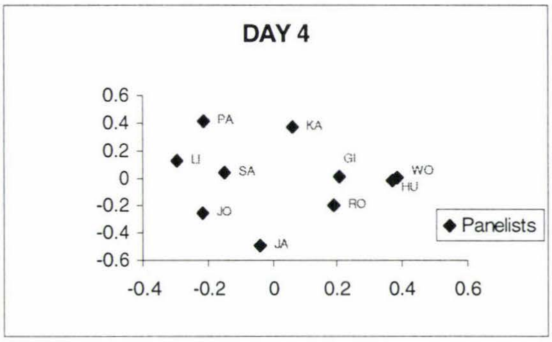
Chewiness

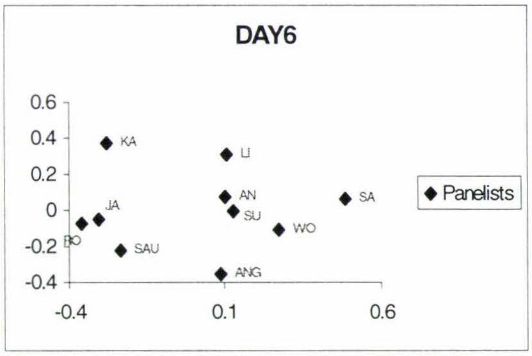
☐

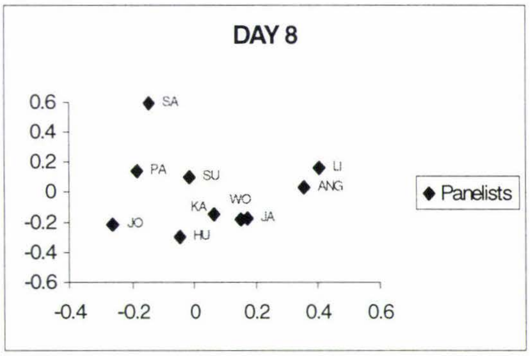
	Cheese	**Jelly** *beans*	*Salami*	
0	2	6.5	8	**10**

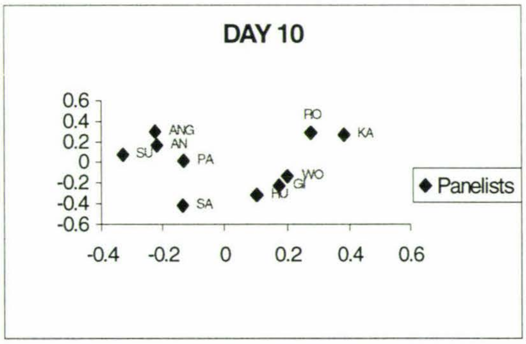
Appendix 3.4 GPA Plots

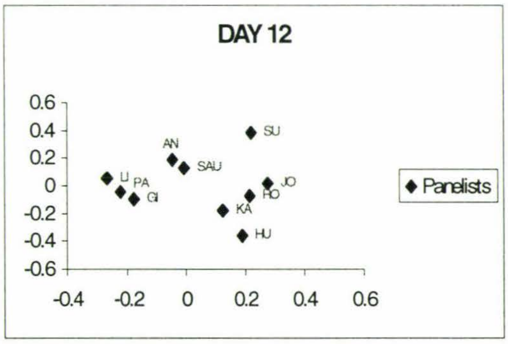












Appendix 3.5 Sensory and Physical Measurements of Chops

Table A3.5a Average scores of sensory attributes for chops

Sample, Cooking Condition[1]	Initial Juice	Hardness	Cohesive	Pork Flavour	Sustained Juice	Chewiness
1 ($E^{120}I^{82}$)	2.12^{cb}	6.03^{a}	4.68^{a}	5.24^{ab}	4.23^{abc}	5.89^{a}
2 ($E^{131}I^{94}$)	1.29^{c}	6.24^{a}	5.11^{a}	4.18^{ab}	3.54^{bcd}	5.83^{a}
3 ($E^{131}I^{70}$)	3.41^{ab}	5.65^{a}	4.67^{a}	5.49^{a}	4.62^{ab}	5.88^{a}
4 ($E^{160}I^{100}$)	0.85^{c}	5.30^{a}	3.87^{a}	4.60^{ab}	2.87^{d}	5.41^{a}
5 ($E^{160}I^{82}$)	1.51^{c}	5.73^{a}	5.25^{a}	4.88^{ab}	3.83^{abcd}	5.94^{a}
6 ($E^{160}I^{65}$)	4.15^{a}	4.78^{a}	4.63^{a}	5.89^{a}	4.80^{a}	5.61^{a}
7 ($E^{188}I^{94}$)	1.49^{c}	5.47^{a}	4.63^{a}	3.41^{b}	3.20^{cd}	5.58^{a}
8 ($E^{188}I^{70}$)	3.91^{a}	5.29^{a}	4.81^{a}	5.27^{ab}	4.86^{a}	5.66^{a}
9 ($E^{200}I^{82}$)	1.45^{c}	5.38^{a}	4.15^{a}	4.31^{ab}	3.50^{bcd}	5.24^{a}

[1] E-external temperature°C; I-Internal Temperature°C

[2] Means in the same column with same letter are not significantly different ($p<0.05$)

[3] All scores input on a 10 cm line where 0 = not juicy, soft, falls apart, no pork flavour, not chewy and 10= very juicy, hard, stays together, strong pork flavour, very juicy, very chewy

Table A3.5b Average scores of physical measurements for chops

Sample, Cooking Condition[1]	Drip Loss %	Evaporation Loss %	Cooking Time (min / Kg)	L*	a*	b*	Maximum Force (N)
1 ($E^{120}I^{82}$)	13.35^{ab}	11.20^{c}	20.09^{ab}	70.84^{a}	4.72^{a}	10.00^{a}	48.87^{ab}
2 ($E^{131}I^{94}$)	15.60^{a}	16.29^{cd}	23.43^{a}	68.53^{ab}	5.13^{a}	11.56^{a}	49.56^{ab}
3 ($E^{131}I^{70}$)	9.55^{abc}	8.73^{d}	12.27^{c}	68.03^{ab}	6.08^{a}	10.38^{a}	47.67^{ab}
4 ($E^{160}I^{100}$)	8.85^{abc}	29.13^{ab}	28.22^{a}	64.01^{b}	7.03^{a}	11.91^{a}	41.92^{abc}
5 ($E^{160}I^{82}$)	9.22^{abc}	20.26^{bc}	14.30^{bc}	69.26^{ab}	5.48^{a}	10.13^{a}	45.34^{abc}
6 ($E^{160}I^{65}$)	6.45^{c}	13.65^{c}	13.33^{bc}	69.56^{ab}	6.61^{a}	10.85^{a}	33.05^{c}
7 ($E^{188}I^{94}$)	6.07^{c}	34.82^{a}	20.15^{ab}	70.13^{ab}	4.85^{a}	10.09^{a}	44.25^{abc}
8 ($E^{188}I^{70}$)	6.61^{bc}	17.62^{cd}	10.91^{c}	73.62^{a}	5.33^{a}	10.27^{a}	52.31^{a}
9 ($E^{200}I^{82}$)	7.63^{bc}	20.28^{bc}	14.48^{bc}	68.71^{ab}	6.43^{a}	9.43^{a}	36.17^{bc}

[1] E-external temperature°C; I-Internal Temperature°C

[2] Means in the same column with same letter are not significantly different ($p<0.05$)

Appendix 3.6 Sensory and Physical Measurements of Fillets

Table A3.6a Average scores of sensory attributes for fillets

Sample, Cooking Condition[1]	Initial Juice	Hardness	Cohesive	Pork Flavour	Sustained Juice	Chewiness
1 (E^{120}I^{82})	3.77^{cd}	2.75^{a}	3.50^{a}	5.03^{a}	5.32^{abcd}	3.84^{a}
2 (E^{131}I^{94})	2.32^{de}	2.83^{a}	3.21^{a}	5.30^{a}	4.22^{cd}	4.77^{a}
3 (E^{131}I^{70})	5.12^{abc}	2.87^{a}	3.51^{a}	6.10^{a}	5.63^{a}	4.37^{a}
4 (E^{160}I^{100})	1.28^{e}	3.06^{a}	2.73^{a}	4.77^{a}	4.14^{d}	4.57^{a}
5 (E^{160}I^{82})	4.96^{abc}	2.89^{a}	3.53^{a}	5.91^{a}	5.36^{abc}	4.42^{a}
6 (E^{160}I^{65})	6.38^{a}	3.97^{a}	3.87^{a}	6.11^{a}	5.46^{ab}	4.95^{a}
7 (E^{188}I^{94})	2.37^{de}	3.25^{a}	3.88^{a}	5.88^{a}	4.28^{bcd}	4.40^{a}
8 (E^{188}I^{70})	5.41^{ab}	2.80^{a}	3.44^{a}	6.19^{a}	5.43^{abc}	4.14^{a}
9 (E^{200}I^{82})	3.99^{bc}	3.64^{a}	3.62^{a}	6.17^{a}	5.11^{abcd}	4.21^{a}

[1] E-external temperature°C; I-Internal Temperature°C

[2] Means in the same column with same letter are not significantly different ($p<0.05$)

[3] All scores input on a 10 cm line where 0 = not juicy, soft, falls apart, no pork flavour, not chewy and 10= very juicy, hard, stays together, strong pork flavour, very juicy, very chewy

Table A3.6b Average scores of physical measurements for fillets

Sample, Cooking Condition[1]	Drip Loss %	Evaporation Loss %	Cooking Time (min/Kg)	L*	a*	B*	Maximum Force (N)
1 (E^{120}I^{82})	2.14^{a}	17.69^{cde}	110.61^{b}	66.70^{a}	4.90^{c}	12.36^{ab}	30.62^{a}
2 (E^{131}I^{94})	4.93^{a}	30.71^{ab}	149.79^{a}	62.13^{ab}	5.99^{bc}	14.35^{ab}	29.48^{a}
3 (E^{131}I^{70})	7.25^{a}	8.61^{e}	61.90^{d}	63.82^{ab}	8.47^{b}	13.50^{ab}	31.53^{a}
4 (E^{160}I^{100})	1.54^{a}	40.78^{a}	176.86^{a}	62.26^{ab}	5.53^{c}	15.28^{a}	33.6^{a}
5 (E^{160}I^{82})	3.00^{a}	20.44^{bcd}	92.27^{bcd}	63.50^{ab}	6.76^{bc}	11.75^{b}	33.29^{a}
6 (E^{160}I^{65})	1.09^{a}	19.22^{cd}	100.69^{bc}	58.83^{b}	12.41^{a}	11.91^{b}	34.52^{a}
7 (E^{188}I^{94})	1.46^{a}	30.58^{ab}	90.33^{bcd}	62.73^{ab}	5.59^{c}	12.90^{ab}	31.68^{a}
8 (E^{188}I^{70})	1.35^{a}	16.10^{de}	63.29^{d}	63.18^{ab}	6.43^{bc}	13.26^{ab}	39.39^{a}
9 (E^{200}I^{82})	1.42^{a}	26.57^{bc}	69.35^{cd}	59.66^{b}	4.34^{c}	14.01^{ab}	32.97^{a}

[1] E-external temperature°C; I-Internal Temperature°C

[2] Means in the same column with same letter are not significantly different ($p<0.05$)

Appendix 3.7 Sensory and Physical Measurements of Leg Roasts

Table A3.7a Average scores of sensory attributes for leg roasts

Sample, Cooking Condition[1]	Initial Juice	Hardness	Cohesive	Pork Flavour	Sustained Juice	Chewiness
1 ($E^{120}I^{82}$)	1.68^{a}	4.44^{ab}	4.25^{ab}	4.57^{ab}	3.58^{b}	5.34^{a}
2 ($E^{131}I^{94}$)	1.89^{a}	3.16^{bc}	2.31^{cd}	4.80^{ab}	3.28^{b}	5.00^{ab}
3 ($E^{131}I^{70}$)	2.40^{a}	4.91^{a}	4.34^{ab}	5.09^{ab}	4.40^{ab}	5.60^{a}
4 ($E^{160}I^{100}$)	1.45^{a}	2.00^{c}	1.20^{d}	3.88^{b}	3.41^{b}	4.05^{b}
5 ($E^{160}I^{82}$)	1.74^{a}	4.60^{ab}	3.87^{ab}	4.25^{ab}	3.66^{ab}	5.68^{a}
6 ($E^{160}I^{65}$)	2.05^{a}	4.37^{ab}	4.62^{a}	6.04^{a}	4.81^{a}	5.41^{a}
7 ($E^{188}I^{94}$)	1.40^{a}	3.52^{ab}	2.40^{cd}	3.95^{b}	3.30^{b}	4.69^{ab}
8 ($E^{188}I^{70}$)	2.24^{a}	4.92^{a}	4.46^{a}	4.65^{ab}	4.31^{ab}	5.86^{a}
9 ($E^{200}I^{82}$)	1.98^{a}	3.75^{ab}	3.01^{bc}	4.88^{ab}	4.17^{ab}	5.29^{a}

[1] E-external temperature°C; I-Internal Temperature°C

[2] Means in the same column with same letter are not significantly different ($p<0.05$)

[3] All scores input on a 10 cm line where 0 = not juicy, soft, falls apart, no pork flavour, not chewy and 10= very juicy, hard, stays together, strong pork flavour, very juicy, very chewy

Table A3.7b Average scores of physical measurements for leg roasts

Sample, Cooking Condition[1]	Drip Loss %	Evaporation Loss %	Cooking Time (min/kg)	L*	a*	b*	Maximum Force(N)
1 ($E^{120}I^{82}$)	5.76^{a}	30.23^{bc}	41.92^{ab}	60.35^{ab}	4.91^{a}	14.53^{bc}	27.50^{b}
2 ($E^{131}I^{94}$)	5.89^{a}	33.87^{abc}	50.77^{ab}	58.43^{b}	4.87^{a}	16.48^{ab}	27.46^{b}
3 ($E^{131}I^{70}$)	4.19^{a}	25.48^{c}	34.70^{b}	62.91^{ab}	5.69^{a}	12.03^{c}	45.90^{a}
4 ($E^{160}I^{100}$)	5.85^{a}	42.29^{a}	69.03^{a}	60.50^{ab}	4.79^{a}	16.29^{ab}	26.48^{b}
5 ($E^{160}I^{82}$)	4.85^{a}	32.67^{abc}	42.02^{ab}	63.29^{ab}	4.58^{a}	11.75^{c}	45.57^{a}
6 ($E^{160}I^{65}$)	4.21^{a}	24.51^{c}	30.94^{b}	59.82^{b}	5.79^{a}	12.90^{c}	29.73^{b}
7 ($E^{188}I^{94}$)	4.44^{a}	39.51^{ab}	45.14^{ab}	64.08^{ab}	4.62^{a}	17.79^{a}	26.59^{b}
8 ($E^{188}I^{70}$)	2.44^{a}	34.46^{abc}	29.37^{b}	63.41^{ab}	5.72^{a}	11.87^{c}	40.68^{ab}
9 ($E^{200}I^{82}$)	2.53^{a}	42.23^{a}	31.34^{b}	66.90^{a}	5.82^{a}	13.75^{bc}	33.87^{ab}

[1] E-external temperature°C; I-Internal Temperature°C

[2] Means in the same column with same letter are not significantly different ($p<0.05$)

Appendix 3.8 Sensory and Physical Measurements of Loin Roasts

Table A3.8a Average scores of sensory attributes for loin roasts

Sample, Cooking Condition[1]	Initial Juice	Hardness	Cohesive	Pork Flavour	Sustained Juice	Chewiness
1 ($E^{120}I^{82}$)	1.34^{b}	4.58^{ab}	3.38^{abcd}	4.24^{a}	3.11^{b}	5.47^{ab}
2 ($E^{131}I^{94}$)	1.10^{b}	3.53^{bc}	2.87^{cde}	4.33^{a}	3.33^{b}	4.61^{bc}
3 ($E^{131}I^{70}$)	3.61^{a}	4.59^{ab}	4.58^{a}	5.81^{a}	5.54^{a}	5.98^{a}
4 ($E^{160}I^{100}$)	1.43^{b}	2.45^{c}	2.03^{de}	4.80^{a}	2.70^{b}	4.53^{bc}
5 ($E^{160}I^{82}$)	1.71^{b}	3.20^{bc}	3.05^{bcde}	4.51^{a}	2.77^{b}	4.56^{bc}
6 ($E^{160}I^{65}$)	2.34^{ab}	4.50^{ab}	4.28^{abc}	4.43^{a}	3.68^{b}	5.39^{ab}
7 ($E^{188}I^{94}$)	1.27^{b}	2.32^{c}	1.66^{e}	4.62^{a}	2.94^{b}	3.85^{c}
8 ($E^{188}I^{70}$)	1.79^{b}	3.52^{bc}	3.11^{bcd}	4.72^{a}	3.06^{b}	4.47^{bc}
9 ($E^{200}I^{82}$)	1.63^{b}	5.01^{a}	4.37^{ab}	5.18^{a}	3.57^{b}	5.51^{ab}

[1] E-external temperature°C; I-Internal Temperature°C

[2] Means in the same column with same letter are not significantly different ($p<0.05$)

[3] All scores input on a 10 cm line where 0 = not juicy, soft, falls apart, no pork flavour, not chewy and 10= very juicy, hard, stays together, strong pork flavour, very juicy, very chewy

Table A3.8b Average scores of physical measurements for loin roasts

Sample, Cooking Condition[1]	Drip Loss (%)	Evaporation Loss (%)	Cooking Time (min/kg)	L*	a*	b*	Maximum Force (N)
1 ($E^{120}I^{82}$)	7.36^{a}	22.23^{cd}	72.79^{ab}	68.33^{abc}	2.88^{a}	14.25^{bc}	32.19^{abc}
2 ($E^{131}I^{94}$)	6.01^{a}	30.16^{abc}	72.86^{ab}	65.48^{abc}	3.63^{a}	15.34^{b}	13.77^{d}
3 ($E^{131}I^{70}$)	4.73^{a}	19.68^{d}	46.22^{b}	64.48^{bc}	3.16^{a}	12.49^{bc}	44.55^{a}
4 ($E^{160}I^{100}$)	8.15^{a}	36.14^{a}	80.74^{a}	65.16^{abc}	4.05^{a}	18.53^{a}	25.03^{bcd}
5 ($E^{160}I^{82}$)	6.91^{a}	27.73^{abcd}	57.84^{ab}	66.80^{abc}	3.17^{a}	11.96^{c}	24.26^{bcd}
6 ($E^{160}I^{65}$)	6.17^{a}	19.33^{d}	40.83^{b}	70.78^{ab}	3.21^{a}	11.54^{c}	37.72^{ab}
7 ($E^{188}I^{94}$)	2.59^{a}	37.80^{a}	62.39^{ab}	63.50^{c}	3.15^{a}	15.40^{b}	43.80^{a}
8 ($E^{188}I^{70}$)	6.91^{a}	24.73^{bcd}	44.03^{b}	71.78^{a}	1.58^{a}	13.93^{bc}	21.38^{cd}
9 ($E^{200}I^{82}$)	4.95^{a}	32.98^{ab}	54.78^{ab}	67.21^{abc}	3.08^{a}	12.14^{c}	44.92^{a}

[1] E-external temperature°C; I-Internal Temperature°C

[2] Means in the same column with same letter are not significantly different ($p<0.05$)

Appendix 3.9 Sensory and Physical Measurements of Shoulder Roasts

Table A3.9a Average scores of sensory attributes for shoulder roasts

Sample, Cooking Condition[1]	Initial Juice	Hardness	Cohesive	P.Flavour	Sustained Juice	Chewiness
1 ($E^{120}I^{82}$)	3.21^{a}	3.15^{ab}	3.19^{abc}	5.25^{a}	4.80^{a}	4.00^{a}
2 ($E^{131}I^{94}$)	1.30^{b}	2.76^{ab}	2.20^{bc}	5.60^{a}	3.79^{a}	4.78^{a}
3 ($E^{131}I^{70}$)	2.51^{ab}	3.55^{ab}	3.55^{ab}	5.59^{a}	3.94^{a}	4.40^{a}
4 ($E^{160}I^{100}$)	1.84^{ab}	2.17^{b}	1.82^{c}	4.90^{a}	3.82^{a}	3.75^{a}
5 ($E^{160}I^{82}$)	2.47^{ab}	3.04^{ab}	2.94^{abc}	4.98^{a}	4.19^{a}	4.24^{a}
6 ($E^{160}I^{65}$)	2.94^{a}	3.84^{a}	4.14^{a}	6.02^{a}	4.83^{a}	4.90^{a}
7 ($E^{188}I^{94}$)	2.97^{a}	2.44^{ab}	2.78^{abc}	5.08^{a}	4.29^{a}	3.87^{a}
8 ($E^{188}I^{70}$)	2.88^{ab}	3.69^{a}	3.91^{a}	4.79^{a}	4.35^{a}	4.39^{a}
9 ($E^{200}I^{82}$)	2.55^{ab}	3.51^{ab}	3.11^{abc}	5.68^{a}	4.25^{a}	4.60^{a}

[1] E-external temperature°C; I-Internal Temperature°C

[2] Means in the same column with same letter are not significantly different ($p<0.05$)

[3] All scores input on a 10 cm line where 0 = not juicy, soft, falls apart, no pork flavour, not chewy and 10= very juicy, hard, stays together, strong pork flavour, very juicy, very chewy

Table A3.9b Average scores of physical measurements for shoulder roasts

Sample, Cooking Condition[1]	Drip Loss (%)	Evaporation Loss (%)	Cooking Time (min/kg)	L*	a*	b*	Maximum Force (N)
1 ($E^{120}I^{82}$)	4.86^{a}	24.84^{bc}	66.92^{ab}	60.96^{b}	5.88^{a}	11.32^{c}	18.64^{a}
2 ($E^{131}I^{94}$)	6.32^{a}	33.01^{abc}	68.67^{ab}	63.04^{ab}	5.01^{ab}	12.56^{bc}	29.08^{a}
3 ($E^{131}I^{70}$)	7.93^{a}	23.64^{c}	50.22^{ab}	63.33^{ab}	4.09^{ab}	12.66^{bc}	26.79^{a}
4 ($E^{160}I^{100}$)	3.44^{a}	43.27^{a}	81.91^{a}	67.90^{a}	3.78^{ab}	16.03^{a}	21.23^{a}
5 ($E^{160}I^{82}$)	3.55^{a}	33.43^{abc}	50.71^{ab}	64.85^{ab}	3.74^{ab}	12.12^{c}	21.68^{a}
6 ($E^{160}I^{65}$)	4.99^{a}	23.98^{c}	39.80^{b}	60.64^{b}	6.14^{a}	13.52^{abc}	22.02^{a}
7 ($E^{188}I^{94}$)	6.55^{a}	37.28^{a}	63.02^{ab}	62.34^{ab}	2.82^{b}	15.38^{ab}	18.62^{a}
8 ($E^{188}I^{70}$)	2.78^{a}	34.62^{ab}	38.24^{b}	63.87^{ab}	5.54^{a}	13.22^{abc}	26.48^{a}
9 ($E^{200}I^{82}$)	3.75^{a}	40.86^{a}	36.68^{b}	62.67^{ab}	5.03^{ab}	13.34^{abc}	28.14^{a}

[1] E-external temperature°C; I-Internal Temperature°C

[2] Means in the same column with same letter are not significantly different ($p<0.05$)

[3] All scores input on a 10 cm line where 0 = not juicy, soft, falls apart, no pork flavour, not chewy and 10= very juicy, hard, stays together, strong pork flavour, very juicy, very chewy

Appendix 3.10 Sensory and Physical Measurements of Scotch Roasts

Table A3.10a Average scores of sensory attributes for scotch roasts

Sample, Cooking Condition[1]	Initial Juice	Hardness	Cohesive	Pork Flavour	Sustained Juice	Chewiness
1 ($E^{120}I^{82}$)	2.19^{bc}	2.41^{bc}	2.70^{bc}	4.80^{a}	4.07^{ab}	3.85^{bc}
2 ($E^{131}I^{94}$)	1.78^{c}	3.69^{ab}	3.42^{ab}	5.41^{a}	4.23^{ab}	5.37^{a}
3 ($E^{131}I^{70}$)	3.80^{a}	3.82^{ab}	3.87^{ab}	5.83^{a}	5.29^{a}	4.48^{abc}
4 ($E^{160}I^{100}$)	2.40^{abc}	1.85^{c}	1.75^{c}	5.58^{a}	4.25^{ab}	3.34^{c}
5 ($E^{160}I^{82}$)	2.57^{abc}	4.12^{a}	4.03^{ab}	5.45^{a}	4.44^{ab}	5.17^{a}
6 ($E^{160}I^{65}$)	3.83^{a}	3.41^{ab}	3.44^{ab}	6.04^{a}	5.05^{ab}	4.52^{ab}
7 ($E^{188}I^{94}$)	1.68^{c}	3.28^{abc}	3.03^{abc}	5.55^{a}	4.00^{b}	4.37^{abc}
8 ($E^{188}I^{70}$)	3.51^{ab}	4.46^{a}	4.30^{a}	5.68^{a}	4.67^{ab}	4.84^{ab}
9 ($E^{200}I^{82}$)	2.28^{abc}	3.99^{a}	4.12^{ab}	5.86^{a}	4.77^{ab}	5.21^{a}

[1] E-external temperature°C; I-Internal Temperature°C

[2] Means in the same column with same letter are not significantly different ($p<0.05$)

[3] All scores input on a 10 cm line where 0 = not juicy, soft, falls apart, no pork flavour, not chewy and 10= very juicy, hard, stays together, strong pork flavour, very juicy, very chewy

Table A3.10b Average scores of physical measurements for scotch roasts

Sample, Cooking Condition[1]	Drip Loss (%)	Evaporation Loss (%)	Cooking Time (min/kg)	L*	a*	b*	Maximum Force (N)
1 ($E^{120}I^{82}$)	3.45^{a}	20.65^{c}	100.72^{bc}	61.28^{a}	8.16^{a}	13.28^{abc}	19.83^{cd}
2 ($E^{131}I^{94}$)	3.76^{a}	38.52^{ab}	145.79^{a}	56.98^{ab}	6.07^{a}	16.24^{a}	41.77^{a}
3 ($E^{131}I^{70}$)	2.31^{a}	19.18^{c}	76.31^{bcd}	59.57^{a}	7.92^{a}	13.20^{bc}	29.21^{abc}
4 ($E^{160}I^{100}$)	2.22^{a}	39.59^{a}	106.99^{b}	51.54^{b}	7.12^{a}	11.23^{c}	12.47^{d}
5 ($E^{160}I^{82}$)	3.33^{a}	31.65^{ab}	73.31^{cd}	56.54^{ab}	7.26^{a}	13.11^{bc}	28.86^{abc}
6 ($E^{160}I^{65}$)	2.52^{a}	20.19^{c}	48.47^{d}	55.56^{ab}	6.92^{a}	13.01^{bc}	24.12^{bcd}
7 ($E^{188}I^{94}$)	1.91^{a}	39.90^{a}	87.60^{bc}	57.22^{ab}	6.58^{a}	14.58^{ab}	28.65^{abc}
8 ($E^{188}I^{70}$)	2.12^{a}	28.24^{bc}	49.31^{d}	57.38^{ab}	7.78^{a}	13.58^{abc}	28.20^{abc}
9 ($E^{200}I^{82}$)	2.27^{a}	34.64^{ab}	48.21^{d}	57.25^{ab}	7.03^{a}	12.89^{bc}	35.25^{ab}

[1] E-external temperature°C; I-Internal Temperature°C

[2] Means in the same column with same letter are not significantly different ($p<0.05$)

Appendix 4.1 Consumer Evaluation of Pork Samples

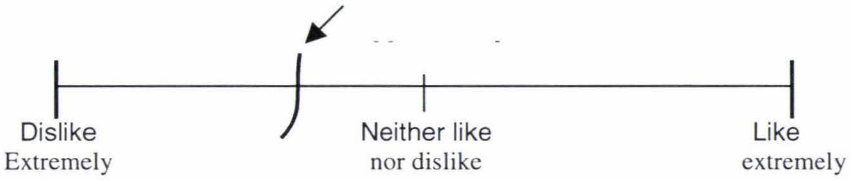
Dear consumer, thank you for participating in this important work for the Australian pork industry.

You will shortly be given FIVE samples. For each one, please rate how much you like the:

- **Colour**
- **Firmness/chewiness**
- **Juiciness**
- **Flavour**
- **Sample overall**

Please answer all FIVE questions for each sample. Indicate how you would rate each of the above by placing a mark on the scale provided.

e.g.: If you don't like the sample, but not extremely, then you *could* mark as follows:



Evaluate the samples in the order shown on this form – the three-digit sample number is shown in the top right-hand corner of each page.

Between each sample, please cleanse your mouth by eating a piece of the plain water cracker provided and drinking some of the filtered water.

After a break, you will be asked to evaluate another FIVE samples.

Finally, you will be asked to fill out a short SURVEY FORM about yourself. All information will be anonymous, and will only be used within this project.

Thank you for your time and effort today – happy eating!

Look at your FIRST sample:

How do you feel about the **COLOUR**? ☐

Dislike extremely	Neither like nor dislike	Like extremely

Now put a piece of the sample in your mouth and chew, then answer the next four questions:

How do you feel about the **FIRMNESS/CHEWINESS** of the sample? ☐

Dislike extremely	Neither like nor dislike	Like extremely

How do you feel about the **JUICINESS** of the sample? ☐

Dislike extremely	Neither like nor dislike	Like extremely

How do you feel about the **FLAVOUR** of the sample? ☐

Dislike extremely	Neither like nor dislike	Like extremely

What is your **OVERALL** feeling about the sample? ☐

Dislike extremely	Neither like nor dislike	Like extremely

☐ Please check that you have marked ALL five scales on this page, and then tick this box.

Have some cracker and water, then go on to the second sample ➠

Look at your SECOND sample:

How do you feel about the **COLOUR**?

Dislike extremely	Neither like nor dislike	Like extremely

☐

Now put a piece of the sample in your mouth and chew, then answer the next four questions:

How do you feel about the **FIRMNESS/CHEWINESS** of the sample?

Dislike extremely	Neither like nor dislike	Like extremely

☐

How do you feel about the **JUICINESS** of the sample?

Dislike extremely	Neither like nor dislike	Like extremely

☐

How do you feel about the **FLAVOUR** of the sample?

Dislike extremely	Neither like nor dislike	Like extremely

☐

What is your **OVERALL** feeling about the sample?

Dislike extremely	Neither like nor dislike	Like extremely

☐

☐ Please check that you have marked ALL five scales on this page, and then tick this box.

Have some cracker and water, then go on to the third sample ➠

Look at your THIRD sample:

How do you feel about the **COLOUR**? ☐

Dislike extremely	Neither like nor dislike	Like extremely

Now put a piece of the sample in your mouth and chew, then answer the next four questions:

How do you feel about the **FIRMNESS/CHEWINESS** of the sample? ☐

Dislike extremely	Neither like nor dislike	Like extremely

How do you feel about the **JUICINESS** of the sample? ☐

Dislike extremely	Neither like nor dislike	Like extremely

How do you feel about the **FLAVOUR** of the sample? ☐

Dislike extremely	Neither like nor dislike	Like extremely

What is your **OVERALL** feeling about the sample? ☐

Dislike extremely	Neither like nor dislike	Like extremely

☐ Please check that you have marked ALL five scales on this page, and then tick this box.

Have some cracker and water, then go on to the fourth sample ➠

Look at your FOURTH sample:

How do you feel about the **COLOUR**?

Dislike extremely | Neither like nor dislike | Like extremely ☐

Now put a piece of the sample in your mouth and chew, then answer the next four questions:

How do you feel about the **FIRMNESS/CHEWINESS** of the sample?

Dislike extremely | Neither like nor dislike | Like extremely ☐

How do you feel about the **JUICINESS** of the sample?

Dislike extremely | Neither like nor dislike | Like extremely ☐

How do you feel about the **FLAVOUR** of the sample?

Dislike extremely | Neither like nor dislike | Like extremely ☐

What is your **OVERALL** feeling about the sample?

Dislike extremely | Neither like nor dislike | Like extremely ☐

☐ Please check that you have marked ALL five scales on this page, and then tick this box.

<u>Have some cracker and water, then go on to the fifth sample</u> ➠

Look at your FIFTH sample:

How do you feel about the **COLOUR**?

Dislike extremely	Neither like nor dislike	Like extremely

☐

Now put a piece of the sample in your mouth and chew, then answer the next four questions:

How do you feel about the **FIRMNESS/CHEWINESS** of the sample?

Dislike extremely	Neither like nor dislike	Like extremely

☐

How do you feel about the **JUICINESS** of the sample?

Dislike extremely	Neither like nor dislike	Like extremely

☐

How do you feel about the **FLAVOUR** of the sample?

Dislike extremely	Neither like nor dislike	Like extremely

☐

What is your **OVERALL** feeling about the sample?

Dislike extremely	Neither like nor dislike	Like extremely

☐

☐ Please check that you have marked ALL five scales on this page, and then tick this box.

Time for a break!!!

Appendix 4.2 Consumer Survey Form

These questions are about you, and the pork you eat. Please answer ALL questions. The information will be anonymous, and will only be used in this project.

Answer by ticking ☑ or ranking where appropriate, for example $\boxed{3}$

Some of the questions below have as an option "other". If you select this option, please give details.

Office use

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1. What is your gender (tick one)?: ☐

☐ Female ☐ Male

2. What is your age group (tick one)?: ☐

☐ Less than 20 years ☐ 21 to 30 years ☐ 31 to 40 years
☐ 41 to 50 years ☐ 51 to 60 years ☐ Over 60 years

3. What is your ethnic origin?: ☐

____.

4. Which of the following has been your **main** area of activity/employment over the past 12 months (tick one)?: ☐

☐ Full time worker ☐ Part time worker ☐ Self employed
☐ Unemployed ☐ Retired ☐ Student
☐ Houseperson ☐ Other (specify):__________________________.

5. What is your income bracket, and your household's income bracket, for the past twelve months (tick one box for yourself and one for your household): ☐ ☐

	Less than $20,000	$21,000 - $35,000	$36,000 - $50,000	$51,000 - $65,000	$66,000 - $80,000	Above $80,000
Your income:	☐	☐	☐	☐	☐	☐
Household income:	☐	☐	☐	☐	☐	☐

The following relate to cuts of pork meat. <u>DO NOT</u> include bacon, sausages and other processed pork products.

6. How often do you eat pork (tick one)?: ☐

☐ Less than once a fortnight ☐ Once a fortnight

☐ Once a week ☐ More than once a week

7. How often do you eat pork outside of the home (tick one)?: ☐

☐ Never ☐ Less than once per month

☐ 1-2 times per month ☐ More than 2 times per month

8. Do you **buy** the pork for your household (tick one)?: ☐

☐ Always ☐ Never ☐ Sometimes

9. Do you **cook** the pork for your household (tick one)?: ☐

☐ Always ☐ Never ☐ Sometimes

10. Where is the pork you eat at home **usually** bought from (tick one)?: ☐

☐ Supermarket ☐ Butcher ☐ Do not know

☐ Other (specify):_______________________________________.

11. What are the main **three** reasons that influence your consumption of pork? – put a 1 next to the main reason, a 2 next to the second most important reason, and a 3 next to the third most important reason:

☐ Value for money ☐ Easy to cook

☐ Frequent specials in store ☐ Nutritious/ good for you

☐	☐
☐	☐
☐	☐

☐ I like it very much ☐ Other household members like it

☐ Other (specify):________________________________.

☐ Other (specify):________________________________.

☐ Other (specify):________________________________

12. Which **three** cuts of pork do you **like eating** the most – put a 1 next to your favourite cut, a 2 next to your second choice, and a 3 next to your third choice (you can refer to the bottom of page 5 for a list of common pork cuts).

☐ Roast (specify the type if known):________________________.

☐ Roast (specify the type if known):________________________.

☐ Chops (specify the type if known):________________________.

☐ Chops (specify the type if known):________________________.

☐ Steaks (specify the type if known):________________________.

☐ Steaks (specify the type if known):________________________.

☐ Fillet ☐ Diced pork ☐ Pork mince

☐ Pork strips ☐ Schnitzel ☐ Spareribs

☐ Other (specify):________________________________.

☐ Other (specify):________________________________.

13. Which **three** cuts of pork have you **eaten the most** in the last year – put a 1 next to the most common cut, a 2 next to the second most common, and a 3 next to the third most common (you can refer to the bottom of page 5 for a list of common pork cuts).

☐ Roast (specify the type if known):________________________.

☐ Roast (specify the type if known):________________________.

☐ Chops (specify the type if known):________________________.

☐ Chops (specify the type if known):________________________.

☐ Steaks (specify the type if known):________________________.

☐ Steaks (specify the type if known):______________________________.

☐ Fillet

☐ Pork strips

☐ Diced pork

☐ Schnitzel

☐ Pork mince

☐ Spareribs

☐ Other (specify):____.

☐ Other (specify):____.

14. How do you usually **cook** your pork/ have your pork **cooked**? Please indicate **up to three** methods – put a 1 next to the most common method, a 2 next to the second most common, and a 3 next to the third most common.

☐ Roast/Bake

☐ Panfry

☐ Stir-fry

☐ BBQ

☐ Grill

☐ Microwave

☐ Other (specify):____.

☐ Other (specify):____.

15. Do you, or others in your household, trim off the external fat before cooking your pork (tick one)?:

☐ Always

☐ Never

☐ Sometimes

16. How do you like your pork cooked?:

☐ Rare

☐ Medium

☐ Well done

☐ Rare to medium

☐ Medium to well done

17. What is the **main** reason for your choice in the last question (tick one)?:

☐ The colour of the meat

☐ The flavour of the meat

☐ The firmness/chewiness of the meat

☐ The juiciness of the meat

☐ Makes the meat safe to eat

☐ Other (specify):____.

18. What is the **main** way you tell that your pork is cooked the way you like it (tick one)?:

☐ Outside colour

☐ Smell

☐ The way it cuts

☐ Inside colour

☐ Colour of the juices

☐ Just by the cooking time

☐ Other (specify):____.

☐

19. Can you think of any information (that could be displayed on the packages of pork cuts, or elsewhere) that would help you **cook** pork/ have your pork **cooked** more successfully?:

____

____

____

____

____

____

____

____

____

____.

☐
☐
☐
☐

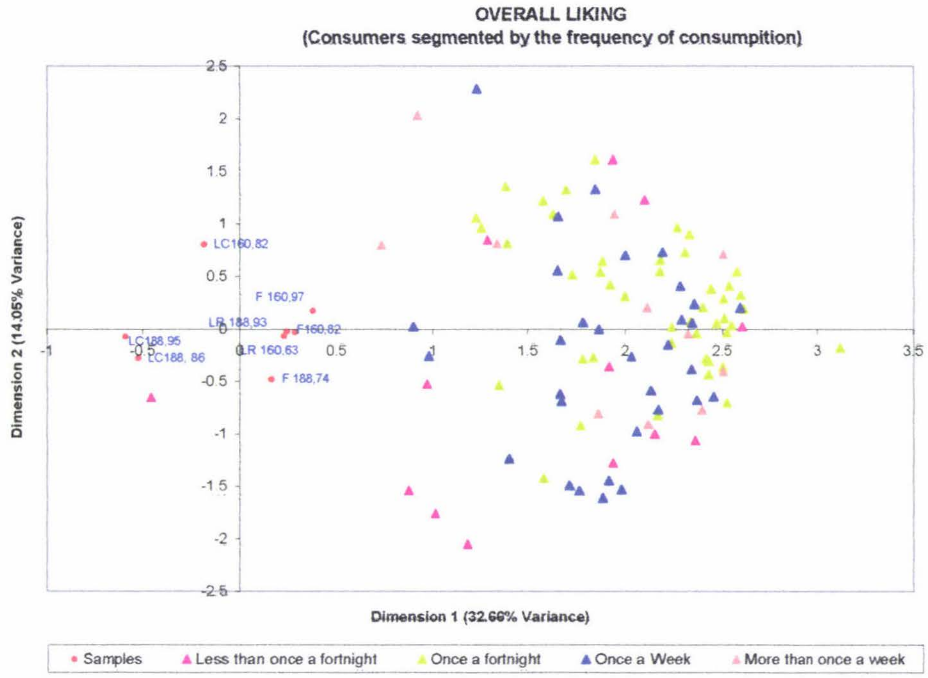
☐ Please check that you have answered ALL of the questions, then tick this box.

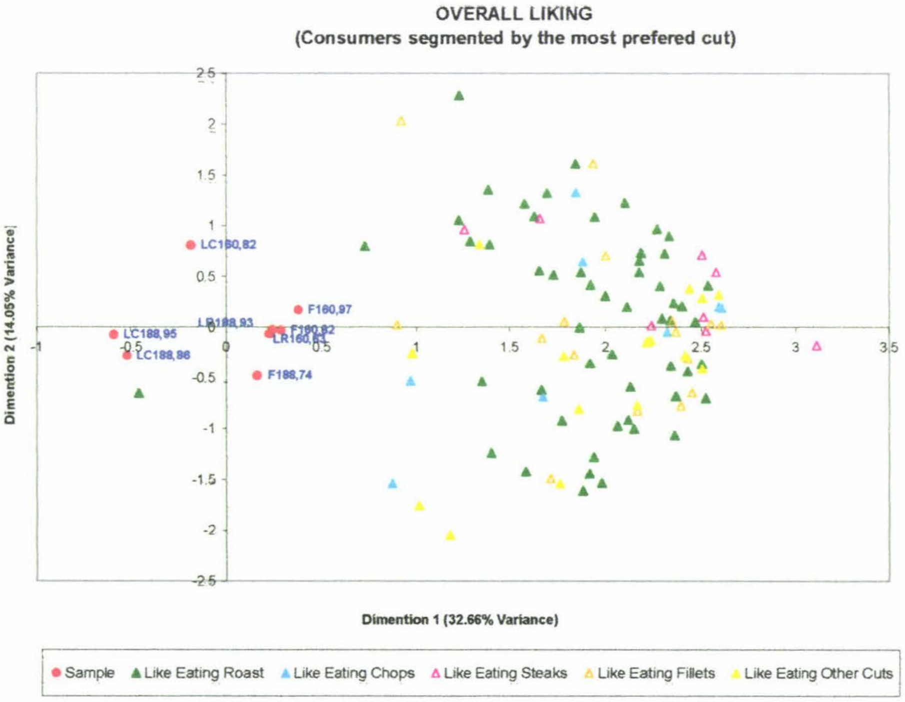
THANK YOU FOR YOUR TIME AND EFFORT TODAY – ALL THE BEST AND KEEP ENJOYING THAT PORK!!!

LIST OF NEW FASHIONED PORK CUTS

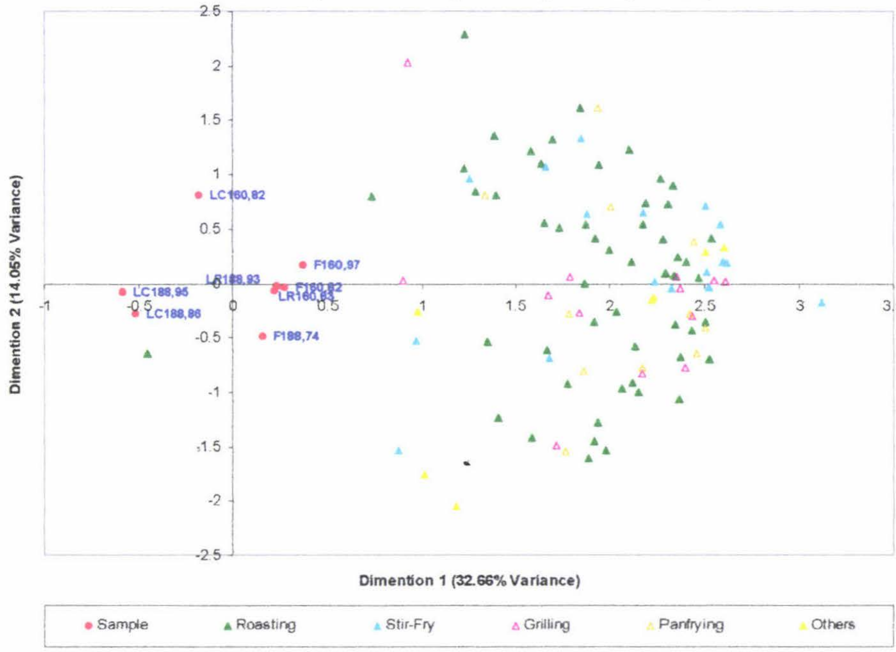
Roasts	Chops and steaks	Other
Leg of pork	**Pork loin chops**	**Pork leg schnitzel**
Pork topside	**Pork forequarter chops**	**Pork leg strips**
Rolled shoulder of pork	**Pork loin cutlets**	**Diced pork**
Pork silverside	**Pork loin steaks**	**Pork mince**
Pork loin	**Pork rump steaks**	**Pork spareribs**
Pork rump miniroast	**Pork leg steaks**	**American style ribs**
Pork scotch (neck)	**Pork midloin butterfly steaks**	**Rack of pork**
Pork fillet	**Pork scotch steaks**	
Rolled loin of pork	Pork loin medallion steaks	

Appendix 4.3 Consumer Segmentation Plots

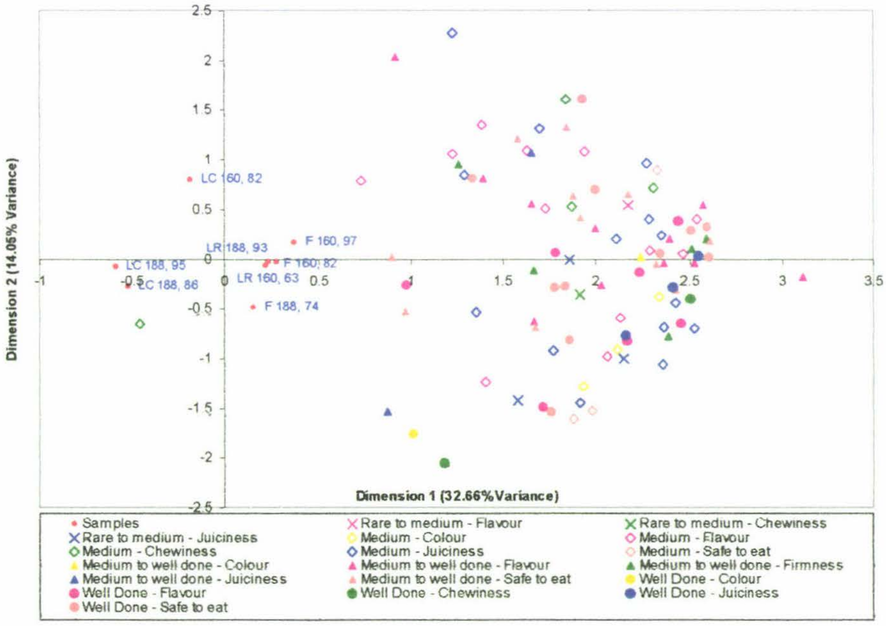




OVERALL LIKING
(Consumers segmented by Cooking Method)



OVERALL LIKING
(Consumers segmented by the preference of doneness and reasons for that preference)



Appendix 4.4 Consumer Survey Data

Data from the CONSUMER SURVEY FORM are summarised below.

Gender	Number (n = 101)
Female	54
Male	47
No response	0

Age grouping	Number (n = 101)
Less than 20 years	5.9
21 to 30 years	24.8
31 to 40 years	19.8
41 to 50 years	24.8
51 to 60 years	16.8
Over 60 years	7.9
No Response	0

Ethnic origin	Number (n = 101)
Australia	63
England	7
New Zealand	4
Scotland	2
China	2
Italy	1
Germany	1
Norway	1
Filipinos	1
No Response	19

Main area of activity	Number (n = 101)
Full time worker	48
Part time worker	16
Student	10
Housewife	9
Self employed	6
Retired	6
Unemployed	1
Other	1
No Response	4

Personal income (AU$/yr)	Number (n = 101)
Less than $20,000	32
$21,000 - $35,000	38
$36,000 - $50,000	16
$51,000 - $65,000	3
$66,000 - $80,000	1
Above $80,000	1
No Response	10

Household income (AU$/yr)	Number (n = 101)
Less than $20,000	15
$21,000 - $35,000	20
$36,000 - $50,000	15
$51,000 - $65,000	15
$66,000 - $80,000	14
Above $80,000	9
No Response	13

How often eat pork	Number (n = 101)
Less than once a fortnight	13
Once a fortnight	45
Once a week	32
More than once a week	11
No Response	0

How often eat pork outside the home	Number (n = 101)
Never	10
Less than once a month	54
1-2 times a month	32
More than 2 times a month	5
No Response	0

Do you buy pork	Number (n = 101)
Always	46
Never	9
Sometimes	46
No Response	0

Do you cook pork	Number (n = 101)
Always	44
Never	8
Sometimes	49
No Response	0

Where is your pork bought	Number (n = 101)
Supermarket	68
Butcher	29
Do not know	1
Other	1
No Response	2

Three main reasons for eating pork	**Number (n = 101)**			
	Main reason	**Second reason**	**Third reason**	**Total score[1]**
I like it very much	32	12	11	131
Easy to cook	10	28	23	109
Nutritious/good for you	16	12	15	87
Value for money	14	13	16	84
Others householders like it	6	19	12	68
Frequent specials in store	11	5	9	52
Other reasons	4	3	3	18
No Response	8	9	12	--

[1] Based on main reason = 3, second reason = 2 and third reason = 1

Three cuts you like eating the most	Number (n = 101)			
	First cut	Second cut	Third cut	Total score[1]
ROASTS				
Leg roast	44	13	7	165
Loin roast	0	2	0	4
Shoulder roast	0	2	1	5
Silverside roast	0	1	0	2
Topside roast	1	1	0	5
Roast unspecified	9	6	0	39
CHOPS				
Loin chops	2	12	12	42
Forequarter chops	3	1	1	12
Chops unspecified	2	7	6	26
STEAKS				
Rump steaks	0	2	2	6
Butterfly steaks	5	7	3	32
Loin steaks	1	2	0	7
Medallion steaks	1	1	2	7
Leg steaks	1	1	1	6
Steaks unspecified	0	2	0	4
CUTS[2]				
All roasts	54	25	8	220
All chops	7	20	19	80
Fillets	16	9	14	80
All steaks	8	15	8	62
Spareribs	5	15	15	60
Diced pork	3	4	9	26
Strips	2	3	8	20
Schnitzel	1	4	8	19
Mince	1	3	5	14
No Response	3	3	6	--

[1] Based on main reason = 3, second reason = 2 and third reason = 1

[2] Sorted by total score

Three cuts you eat the most	Number (n = 101)			
	First cut	Second cut	Third cut	Total score[1]
ROASTS				
Leg roast	30	17	7	131
Loin roast	0	0	1	1
Shoulder roast	1	2	1	8
Silverside roast	0	1	0	2
Topside roast	1	0	1	4
Roast unspecified	11	7	3	50
CHOPS				
Loin chops	9	8	13	56
Forequarter chops	2	3	1	13
Chops unspecified	7	10	6	47
STEAKS				
Rump steaks	1	1	1	6
Butterfly steaks	4	6	1	25
Loin steaks	2	0	1	7
Medallion steaks	1	1	3	8
Leg steaks	1	0	1	4
Steaks unspecified	0	1	0	2
CUTS[2]				
All roasts	43	27	13	196
All chops	18	21	20	116
Fillets	12	10	15	71
Spareribs	6	11	15	55
All steaks	9	9	7	52
Diced pork	4	7	11	37
Strips	4	4	4	24
Mince	1	4	4	15
Schnitzel	0	4	6	14
No Response	4	4	6	--

[1] Based on main reason = 3, second reason = 2 and third reason = 1

[2] Sorted by total score

Three main cooking methods	Number (n = 101)			
	Main reason	Second reason	Third reason	Total score[1,2]
Roast/Bake	53	15	17	206
Stir fry	17	20	24	115
Grill	13	27	15	108
Pan fry	11	24	18	99
BBQ	3	11	19	50
Boil/Casserole	3	2	2	15
Microwave	0	0	1	1
No Response	1	2	5	--

[1] Based on main reason = 3, second reason = 2 and third reason = 1

[2] Sorted by total score

Trim off external fat	Number (n = 101)
Always	30
Never	32
Sometimes	39
No Response	0

Doneness level	Number (n = 101)
Rare	0
Rare to medium	6
Medium	37
Medium to well done	33
Well done	24
No Response	1

Main reason for doneness level	Number (n = 101)
The colour	5
The flavour	31
The firmness/chewiness	12
The juiciness	23
Makes the meat safe	26
Other reasons	1
No Response	3

Main way of determining doneness	Number (n = 101)
Outside colour	11
Smell	3
The way it cuts	19
Inside colour	37
Colour of the juices	19
Cooking time	9
Other ways	2
No Response	1

Information to help cook	Number (n = 101)[1]
Cooking method suggestions	49
Tenderness of the meat	5
Recipe suggestions	23
What the pig has eaten	1
No Response	35

[1] Some people suggested more than one thing