Determining the effect of ageing period, cut type, cooking method and internal temperature on sensory and technological quality of pork

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By

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Executive Summary

The administration of the boar taint vaccine can effectively reduce androstenone and skatole concentrations to minimise risks associated with boar taint and increase intramuscular fat levels as well as reduce male socio-sexual behaviours on-farm. Previous Pork CRC funded research (Channon *et al.* 2013), compared the effect of ageing period, cut type, cooking method and final internal cooking temperature on eating quality attributes of pork, identified that juiciness, flavour, overall liking, quality grade and intramuscular fat content was lower from entire male than surgically castrated males, with females intermediate. Other studies comparing effects on eating quality comparing immunocastrated males and entire males have not evaluated these factors. This information is required as part of the development of the cuts-based eating quality system for the Australian pork industry. Therefore, this study aimed to determine the effect of ageing period, cut type, cooking method and endpoint cooking temperature on eating quality attributes of pork from entire and immunocastrated males.

Thie study involved 40 (Large White x Landrace, PrimeGro™ Genetics) pigs of two genders (entire male and immunocastrated male) with 20 pigs per sex. Three primal cuts (loin, silverside and shoulder) from both sides of the carcase and three cooking methods (roast and stir fry (all primals) and grilling as steaks (loin only)) were evaluated. Each cut was either aged for 2 or 7d post-slaughter and cooked to either a 70 or 75°C endpoint temperature. The objective of this study was to determine the influence and size of these factors, and their interactions, to improve pork consistency and reducing the fail rate of pork to less than 10%. The hypotheses being tested were that entire males will produce pork of poorer eating quality with higher fail rates than immunocastrated males; ageing for 7d post-slaughter, rather than 2d post-slaughter, will improve sensory scores for tenderness, juiciness and flavour; cooking to an endpoint temperature of 70°C, rather than 75°C, will minimize moisture loss and improve consumer scores, particularly for tenderness and juiciness of pork and that eating quality will vary due to cooking method used for the loin, silverside and shoulder primals.

Intramuscular fat levels of the loin, silverside and blade muscles were higher from immunocastrated males compared with entire males. However, gender effects on eating quality were not observed as either a main effect or in any interaction terms involving the other factors investigated in this study - ageing period, endpoint temperature and cooking. Cooking was the major factor influencing pork quality, with differences between cooking method and cut type observed together with interactions with endpoint temperature and/or ageing period. Cuts from the shoulder (blade and chuck tender) were more preferred than those from the loin and silverside Fail rate, based on the percentage of consumer evaluations that scored either 1 (unacceptable) or 2 (below average) for quality grade was slightly higher for pork from entire males than immunocastrates (17.8 vs. 15.7%, respectively). Similarly, more consumers responded that they would not repurchase pork from entire males than from immunocastrates (24.1 vs. 20.2%, respectively). Ageing period, as a main effect, only influenced overall liking scores. Endpoint temperature was a significant term in the interactions with cut type for flavour, overall liking, quality grade and re-purchase intention and with cooking method (roast or stir fry) for aroma. Cooking to an endpoint temperature of 75°C reduced juiciness scores of loin steaks relative to the average of all other cuts and increased cooking losses compared to cooking to 70°C. Across all seven cut x cooking method combinations, loin steaks and roasts and stir fry from the silverside obtained the lowest scores for tenderness, juiciness, overall liking, quality grade and re-purchase intention. Both the roast and stir fry from the shoulder had low fail rates (5.6 and 5.3%, respectively), meeting the fail rate objective for quality grade of <10%. Neither the loin or silverside achieved the fail rate objective. Fail rates were higher for silverside roasts (26.9%), loin

steak (25%) and silverside stir fry (21.9%) followed by loin roast (19.1%) and loin stir fry (13.4%).

Overall liking of pork was influenced, in order of importance, by flavour, tenderness, juiciness. Aroma was not a significant term in the predictive equation for overall liking even though entire males were involved in this study and the boar taint incidence in entire male pigs was 10%. These results highlighted further investigations are required to optimize the pathway interventions that different supply chains can implement to improve overall liking and reduce the fail rate for quality grade to at least <10%. Although this was attained for shoulder cuts in this study, these results need to be extended to higher value pork cuts when different cooking methods are used

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1 Introduction

Immunocastrated males were originally included in the design of a large eating quality project reported by Channon *et al.* (2013), together with females, entire males and surgical castrates, to fill knowledge gaps for impact of ageing, cooking method, cut type and final degree of doneness on sensory evaluation of pork. However, following completion of assays by Frontage Laboratories in China, whom Pfizer Animal Health use for determining skatole and androstenone concentrations in pork adipose tissue, it was identified that levels of androstenone and skatole from immunocastrated males were similar to those of entire male pigs. This suggested that immunocastrated pigs did not receive the second vaccination scheduled to be administered at 16 weeks of age (or it was not effective) – the animals did receive the 10 week vaccination. Studies comparing the effect of gender on pork eating quality involving immunocastrates have not investigated the effect of ageing period and endpoint temperature across a number of different cuts and cooking methods. This study was therefore repeated, with comparisons to be made against entire male pigs as the negative control.

Improvac®, a vaccine developed in Australia and manufactured by Pfizer Inc., is now being used to immunocastrate entire males in Australia, and in many countries overseas, to minimise flavour issues associated with the production of entire males, but this is not widespread. Worldwide interest in Improvac® use is increasing as an alternative to surgical castration. The vaccine contains a modified gonadatropin releasing factor (GnRH) antigen in an aqueous adjuvant system that causes little tissue aggravation when injected. It requires the administration of two injections, one at 10 weeks of age and the other from 4-5 weeks (Dunshea *et al.*, 2001) to two weeks (Lealiifano *et al.*, 2011) prior to slaughter. A delay in administration of the secondary injection of the vaccine to a minimum of two weeks pre-slaughter provides advantages to producers by both maximising growth rate advantages associated with testicular hormone production of entire males and through minimising feed costs, as immunocastration can result in increased feed intake. Immunocastrated male pigs therefore have lower levels of skatole and androstenone in subcutaneous fat due to the inhibition of GnRH. Immunocastrated males are leaner, grow faster and exhibit reduced sexual and aggression activities than entire male pigs. In general, immunologically castrated males produce pork of equivalent quality to females and surgically castrated males and superior to that from entire males (Allison *et al.*, 2009).

Channon *et al.* (2013) reported that juiciness, flavour, overall liking, quality grade and intramuscular fat content were influenced by sex of the pig, with lower scores obtained for pork from entire males than surgical castrates, with females intermediate. Of the 20 entire males involved in this study, four had high androstenone levels (>1µg/g) and three of these were classified as to have boar taint (high (androstenone >1µg/g and skatole >0.2 µg/g). Fail rate, based on the percentage of consumer evaluations that scored either 1 (unacceptable) or 2 (below average) for quality grade was higher for pork from entire males than from females and surgical castrates. Fail rates for re-purchase intention based on scores of either 1 (I definitely would not buy it) or 2 (I probably would not buy it) were also higher for pork from entire males than females and surgical castrates. It was therefore recommended that entire males are not included as part of an eating quality system to deliver pork of guaranteed high eating quality to consumers.

The hypothesis of this study was that different pork cuts from immunocastrated males will be more preferred by consumers and have lower fail rates compared with pork sourced from entire males. It was also hypothesized that ageing for 7d post-slaughter, rather than 2d post-slaughter, would improve sensory scores for tenderness, juiciness and flavour; cooking to an endpoint temperature of 70°C, rather than 75°C, will minimize moisture loss and improve consumer scores, particularly for tenderness and juiciness and eating quality will vary due to cooking method used for the loin, silverside and shoulder primals.

2 Methodology

The study was conducted as a follow up project to 3A-103 1122, due to high levels of both androstenone and skatole of immunocastrated males in that study. In this study, a total of 20 animals per gender (immunocastrated and entire males) were used. Three primal cuts were evaluated (loin, silverside and shoulder) and three cooking methods (roast, stir fry (all primals) and grilling as steaks (loin only)). Each cut was either aged for 2 or 7 days (d) post-slaughter and cooked to either a 70 or 75°C endpoint temperature. The objective of this study was to determine the influence and size of these factors, and their interactions, to improve pork consistency and reduce the fail rate of pork to less than 10%. The hypotheses being tested were that entire males produce pork of lower eating quality to consumers; ageing for 7d post-slaughter, rather than 2d post-slaughter, will improve sensory scores for tenderness, juiciness and flavour; cooking to an endpoint temperature of 70°C, rather than 75°C, will minimize moisture loss and improve consumer scores, particularly for tenderness and juiciness of pork; and eating quality of different cuts will vary with cooking method used.

2.1 Effect of gender, ageing period, cut type, cooking method and endpoint temperature on eating quality of pork

2.1.1 Animal management

A total of 40 pigs (Large White x Landrace, PrimeGro™ Genetics) were sourced for this study from a piggery located in southern New South Wales. At birth in June 2012, piglets were randomly allocated to gender treatment (n=20 per gender) – entire males or immunocastrates. All pigs were injected with iron at birth. Animals allocated to the immunocastration treatment were vaccinated with Improvac at 10 weeks of age and were scheduled to receive their second vaccination at 15 weeks of age. Animals were slaughtered over two slaughter days within the same week at 21 weeks of age, two days apart within the one week in November 2012. Liveweight was obtained for all pigs in this study at birth, at weaning, at 10 and 15 weeks of age at the commencement of the grower and finisher phase, respectively, as well as on the day prior to slaughter. Animals were individually tattooed on the day prior to slaughter to allow for identification of individual carcases on the slaughter floor.

Diet specifications fed to pigs in the finisher phase are shown in Table 1. Pigs in this study were not fed Ractopamine in the finisher diet or treated with pST.

Table 1: Specifications of diets fed to pigs during the weaner, grower and finisher phases in this study

	Diet specifications		
	Weaner (5-15 kg liveweight)	Grower (15-60 kg liveweight)	Finisher (60-100 kg liveweight)
Protein (%)	23.2	18.47	13.81
DE/MJ kg	14.66	13.99	14.00
Fat (%)	5.02	3.51	2.87
Fibre (%)	2.93	4.39	3.29
Lysine (%)	1.46	1.14	0.81

All animals were minimally handled both on farm and at the abattoir and remained in their separate gender x slaughter date groups for the entire finisher period, during transport and in lairage. Pigs were transported 3 km for duration of 10 minutes to the abattoir, unloaded and held in lairage for 17 hours prior to slaughter, with access to water. Each gender group was moved separately to the point of stunning with minimal handling and stunned using 90% carbon dioxide (Butina, Denmark). Following evisceration, a fat sample was obtained from each carcase from the belly, individually labeled and frozen at -20°C until required for analysis.

Hot carcase weight (AUS-MEAT Trim 1) and fat depth at the P2 site, using the Hennessy Grading Probe (Hennessy Grading Systems, Auckland, NZ) was measured and recorded for all carcases and carcases were split prior to chilling. On both slaughter days, carcases were placed in the same chiller, fitted with overhead fans, and conventionally chilled according to standard commercial practice (1-2°C for 24 hours). Measurements of muscle pH and temperature decline post-slaughter were made in the *M. longissimus thoracis et lumborum* (loin) adjacent to the P2 site at 45 min, 90 min, 3 h and 6 h post-slaughter in the left side of the carcase using a portable pH meter fitted with a polypropylene spear-type gel electrode and a separate temperature probe.

At 24 h post-slaughter, cold carcase weight was obtained and carcases were boned. Boneless loin, silverside (*M. biceps femoris*) and shoulders were collected from both sides of each carcase. These primals were then prepared into the required cuts for both sensory and technological quality assessment. For the loin, a 2-3 cm slice was removed from the caudal end and a total of four 2.5 cm thick steaks were then sliced, de-rinded and denuded of subcutaneous fat, labeled and individually vacuum packaged. A 15 cm piece, for roasting, followed by a 10 cm piece for preparation into stir fry samples were then cut, labeled and individually packaged. The remaining piece was used for objective meat quality measurements. For the silverside, a 10 cm roasting piece was firstly cut, followed by another 10 cm piece for stir fry with the remaining muscle used for objective meat quality measurements. The bolar blade (*M. triceps brachii*), for roasting, and chuck tender (*M. supraspinatus*), for stir fry, were removed from the pork shoulder. Two different muscles were used from the shoulder as the bolar blade cut was not large enough to supply meat for both cooking methods and the chuck tender was selected as it was preferred in order to ensure that consumers evaluated the same muscle. All roasting pieces retained rind and subcutaneous fat which was removed by the chef after cooking prior to being assessed by the consumer panel. Within each slaughter day, two carcases per gender were blocked into one pair. Ageing period (2 or 7 days) and endpoint temperature (70 or 75°C) was then randomly allocated to a side within each pair. The four treatment combinations were then allocated to the four sides. The individual samples were labelled during preparation in the boning room with details of carcase side and number, type of primal, gender, ageing period and degree of doneness allocation. Cuts were boxed and frozen at either 2 or 7 days post-slaughter, depending on treatment allocation. In the plant, two shoulders were lost during boning. This was accounted for in the statistical analysis of the sensory data. Pork was then transported by truck in a freezer to Adelaide, where it was held at -18°C until required for sensory assessment.

In summary, the primal cuts used were loin, shoulder and silverside; these were vacuum packaged and aged for two and seven days post-slaughter before freezing. The cooking methods employed for the sensory assessment were grilling (boneless denuded loin steak only), stir frying (loin, shoulder (chuck tender) and silverside) and roasting (loin, shoulder (bolar blade) and silverside) and were cooked to either medium (70°C) or medium/well done (75°C).

2.1.2 Objective measurements

2.1.2.1 Androstenone and skatole

Belly fat samples were analysed for androstenone (surgical castrates, immunocastrates and entire males) and skatole (all genders) by Frontage Laboratories Co., Ltd. (Shanghai, China). The concentration of androstenone was conducted using high performance liquid chromatography with mass spectrometric detection (HPLC/MS/MS). Skatole was determined using high performance liquid chromatography – fluorescence detection (HPLC-FLD).

2.1.2.2 Objective assessments

Muscle pH and temperature and meat colour was determined after ageing for either 2 or 7 d post-slaughter. Muscle samples from all muscles were exposed to air at room temperature for 10 min. Meat colour was determined using a Minolta Chromameter Model CR-400 (calibrated on a white tile) set on the L*, a* and b* system where L* denotes relative lightness (higher L* values = paler meat), a* relative redness (higher a* values = more red) and b* relative yellowness (higher b* values = more yellow), using D65 illumination and a 2° standard observer.

After ageing, the loin and silverside sample was prepared into one 70±5 g block for Warner-Bratzler shear force (WBSF) assessment, a 20 g block for drip loss assessment and remaining trim reserved for analysis of intramuscular fat content. WBSF and drip loss were not determined for the shoulder due to lack of sample. Samples for WBSF assessment and intramuscular fat were then labelled, individually bagged and frozen at -20°C. Samples for WBSF were cooked from frozen state and dependent on internal temperature treatment, cooked in a waterbath preheated to either 70 or 75°C until an internal temperature of 70 or 75°C was attained. Each sample was suspended from a metal rack and cooked in a water bath. Samples were then cooled in iced water for 30 minutes. Samples were dried and weighed to determine cooking loss (expressed as a percentage of weight lost due to cooking) and then stored at 4°C for 24 hours. From each sample, five 1 cm^2 replicate samples were cut parallel to the orientation of muscle fibres and WBSF was measured using a Warner Bratzler shear blade fitted to a Mecmesin BFG500N (Bodine Electric Company, Chicago, USA).

Samples for intramuscular fat measurement were obtained from loin , blade and silverside from each side, labeled, individually vacuum packaged, frozen and -freighted to Silliker Australia, Regents Park, Sydney for analysis using the Ankom method (extraction of crude fat using petroleum ether).

Drip loss was determined using a modified method of Rasmussen and Andersson (1995). A sample of pork loin was cut to a 20 g cube, weighed and weight recorded. The sample was then wrapped in 20 cm^2 piece of square netting. The wrapped sample was then suspended in a 200ml plastic container and left to stand in a 4°C chiller for 24 h, after which it was removed from the container, gently rolled in paper towelling and reweighed to determine percentage drip loss.

2.1.3 Sensory evaluation

The consumer panel was designed to determine sensory attributes of aroma, tenderness, juiciness, flavour and overall liking for each pork sample assessed. Demographic information (gender, household size, age, current purchasing, cooking and consumption habits of fresh pork) was captured for each consumer along with a quality grade and re-purchase intention score for each pork sample evaluated.

The preparation and cooking protocols for the sensory evaluation of pork samples in this study were previously described in the final report for 3A-103 (Channon *et al.* 2013). However, cooking protocols were updated because a different model of oven (Fagor) was used for the roasts in this study. The consumer sensory sessions were conducted at one central location at the University of South Australia (UniSA) sensory facilities based at the city centre campus in Adelaide.

2.1.3.1 Consumer Recruitment

Consumers were recruited by an independent recruitment company (Intuito Market Research). The early process for recruitment included emailing their extensive database of consumers willing to participate in taste testing as well as running advertisements in local Adelaide newspapers (The Advertiser and Sunday Mail).

The specifications for recruitment were that all participants needed to be consumers who had eaten fresh pork (not bacon or ham) in the past month and who were aged between 18 and 65 years. Butchers and other people working with meat production and sales were excluded. Individuals (n=320) were asked to join a panel of eight consumers for approximately one hour at varying times of the day from 10.00 am to 3.00 pm or 2.00 pm to 7.00 pm with three sessions per day on three pre-determined days per week from Monday to Saturday.

Potential participants registered with Intuito either online or over the telephone and were contacted by a recruiter to arrange a time that would suit them to attend. Participants who cancelled their appointments were replaced using the database generated of over 1,000 consumers. Participants were given an honorarium for their participation in the study and were used only once in this study.

2.1.3.2 Allocation of Frozen Samples into Sensory Sessions

The pork samples were transported on 26 November 2012 by refrigerated transport from the processor to the butchery department at the Technical and Further Education (TAFE) Regency campus in Adelaide and arrived on 27 November 2012. The cartons containing the samples were sorted into their pre-allocated sensory session and then stored in a holding freezer at -18°C until required for sensory analysis commencing one week after sample delivery.

The sorting was undertaken in a controlled temperature room (12°C) in the TAFE butchery department. For each sensory session, a total of 20 pieces per session (10 per side) were required:

a) 8 loin steaks
b) 2 loin roasts
c) 2 silverside roasts
d) 2 bolar blade roasts
e) 2 loin stir fry
f) 2 silverside stir fry
g) 2 chuck tender stir fry

Duplicate copies of a one page session labeling document were prepared in advance for every session to indicate which samples (n=20) were required for the sessions. The document showed the session number, gender, final endpoint temperature, carcase number and a list of the 4 digit codes for each sample required for the different cooking methods. Outer labels were also prepared for the labeling of cartons for each session; these included session number, gender, final endpoint temperature and carcase number.

The following method was used to prepare the samples for each session (completed by three people in one day).

- Samples were removed from the cartons and laid out on tables in order of carcase number, from 1 to 40.
- The 20 samples required were located using one copy of the session labeling document, checked off the list and put inside a plastic liner into a carton in a single layer. A separate carton was used for each session and each person was responsible for one sensory session at a time, from 1 to 40.
- Once all 20 samples had been located, the plastic liner was folded over the samples. The duplicate copy of the labeling document was placed on top, the carton sealed, labeled with three outer identification labels and placed onto a pallet in the holding freezer at –18°C. The checked labelling documents were retained.

This process continued until all sessions were completed and placed back into the holding freezer. After sorting into sessions, cartons (n=40) were transported to the SARDI Waite campus at the end of the same day (30 November 2012) and placed into a -18°C freezer immediately on arrival.

2.1.3.3 Thawing and preparation protocols

A thawing protocol developed for samples required per testing day (three sensory sessions per day) was as described by Channon *et al.* (2012) for 3A-103. Briefly, the thawing protocol developed was to remove the cartons (n=3) required for one day of sensory sessions from the -18°C freezer at 8 am or 12 pm (depending on the sensory sessions times for that day) and place them into the 4°C constant temperature room for between 44 and 52 hours. This protocol was also beneficial because as samples were collected from the 4°C room to transport to the testing location, other samples could be removed from -18°C for thawing. Samples were prepared for the sensory sessions between one and seven hours after removal from the 4°C room.

On each day of the sensory sessions the three cartons of samples required were collected from SARDI Waite campus (at either 8 am or 12 pm) and transported to the central testing location at UniSA by car. The cartons were transported in the boot of a car and the journey was approximately 15 minutes. The sensory sessions were undertaken in December 2012. The average minimum temperature in December was 16.0°C (Australian Government Bureau of Meteorology website, Accessed 12 Feb 2013). The samples were not transported under refrigerated conditions due to the short transport time and low ambient temperature.

On arrival at the test location, the samples were removed from the carton. Samples for Sessions 2 and 3 were placed on separate shelves in a domestic fridge (5°C) and preparation commenced with samples for Session 1.

On removal from the carton, the 20 individual samples were checked against the session labelling document to ensure the session contained the correct samples. The 4 digit number was used as the primary identification tool. Each sample was identified by its unique 4 digit number and this ID followed the sample from removal from its vacuum packaging to presentation to the sensory panelist for evaluation.

The preparation method undertaken for each of the primal cuts prior to cooking is described below.

Roast

This cooking method was undertaken on all primal cuts (loin, shoulder: bolar blade and silverside) with six samples roasted in each session, two of each type. The roast pieces were removed from vacuum packaging and labelled with their 4 digit number. A portion was removed from the loin roasts and some of the silverside roasts to cut them to a similar weight and size as the bolar blade pieces. Three roast pieces were placed onto a greaseproof paper lined roasting tray (with removable drip tray) and an oven proof label attached to the tray to identify each piece. Two trays of roasts were required for each session.

A meat thermometer (a stainless steel probe with a 1m lead connected to a digital thermometer on the outside of the oven) was inserted into the centre of each roast and used to monitor the internal temperature of the roast pieces throughout cooking. Each thermometer was also labelled with the matching 4 digit number for the roast. The thermometer alarm preset function was used to set temperatures depending on the final endpoint temperature required for the session. The temperature of the roasts was 1-3°C before cooking commenced.

Grill

This cooking method was undertaken on loin steaks only, with eight steaks in each session. The steaks were removed from the vacuum packaging and labelled with their 4 digit number. They were measured for length, graded into large and small sizes, placed onto a tray and stored at 5°C until required.

The steaks were sorted into small and large sizes based on revised grilling protocols developed from trials with the Silex grill purchased for this study. The grilling trials undertaken are described in further detail in the grilling cooking protocols section below and resulted in different grilling times for different steak sizes, hence the requirement for the loin steaks to be graded prior to being cooked. The temperature of the loin steaks was 5-7°C before cooking commenced.

Stir Fry

This cooking method was undertaken on all primal cuts (loin, shoulder: chuck tender and silverside) with six samples to be stir fried in each session, two of each type. The stir fry primal cuts were removed from vacuum packaging and labelled with their 4 digit numbers. Pieces for stir frying were cut to 50 mm x 10 mm x 10 mm, each weighing about 7 g. Approximately 15 pieces were dissected from each primal cut (12 pieces were required for each session). The 15 pieces were placed into a plastic storage container, labelled on the outside with the 4 digit number and placed in the fridge at 5°C until required. The temperature of the stir fry pieces was 5-7°C before cooking commenced.

2.1.3.4 Cooking Protocols

The different cooking methods undertaken for each of the primal cuts before consumer evaluation are described. The seven samples to be evaluated by each consumer were in a randomised tasting order so the cooking of samples (n=20) could not be done to order.

Roast

The oven utilised at the UniSA facilities was a Fagor single electric oven Model Visual VE101 (Fagor, Mondreagon, Spain). At the start of each day the oven was set to convection mode and pre-heated to the required temperature. Oven trials were completed at a test day at UniSA prior to the start of the study to determine the optimum oven heat and thermometer settings to produce pork roasts cooked to the required degrees of doneness for the study (70°C and 75°C) after a five minute resting period.

As previously reported in APL Project 2009-2269, the roast cooking times were variable (approximately 10 minutes) even with relatively consistent dimensions and weights and regardless of location in the oven. A convection oven setting of 175°C and thermometer settings of 68°C and 73°C (to signal removal of roasts from the oven) would achieve a medium 'degree of doneness' (70°C) and medium/well done 'degree of doneness' (75°C) respectively after a five minute resting period.

The two trays of six roasts were placed on separate shelves in the pre-heated oven approximately 75 minutes before the start of each sensory session. The temperatures of the roasts were monitored throughout the cooking period. Once a roast had reached the required temperature (68°C or 73°C) and the thermometer alarm sounded, the roast and its ID label were removed and placed on a wire rack located on the bench above the oven for the resting period. At the start of each day, the roasts were monitored for temperature during the resting period to ensure the equipment was functioning as expected. After this confirmation, further resting period temperatures were not monitored.

Grill

The grill used for this study was a Silex Grill Model GTTPowersave 10.10-30 (Silex Elektrogerate GmbH, 22143 Hamburg, Germany). When the four steaks were cut from each loin primal from one carcase side, their relative position on the loin (1-4) was recorded. Two steaks were grilled at one time to ensure there would be no confusion or mix up of the loin steak IDs during the grilling and serving procedures.

The loin steaks were measured in length and graded into small (≤130 mm) and large (>130 mm) sizes which resulted in different grilling times for each size to deliver the required final endpoint temperature (Table 2. A grill temperature of 160°C was used and cooking time varied with loin steak size (Table 2).

Table 2: Grilling protocol for different sizes of pork loin steaks for two degrees of doneness (70°C and 75°C)

Loin Steak Size	Required Degree of Doneness (after 2 mins resting)	Grilling Time at 160°C
Small (≤130mm length)	70°C	3 minutes, 10 seconds
Small (≤130mm length)	75°C	3 minutes, 40 seconds
Large (>130mm length)	70°C	3 minutes, 25 seconds
Large (>130mm length)	75°C	3 minutes, 55 seconds

Approximately 30 minutes before the start of the sensory session, the grill was pre-heated to 160°C and cooking commenced. The loin steaks were brushed on each side with rice bran oil before being placed onto the grill plate and the lid lowered. To maintain sample identification once the steaks were placed on the grill, their corresponding labels were secured on either side of the grill stand. Duplicate labels were also placed on the cutting board next to the grill.

At the start of each session, the internal take-off and resting temperatures were measured for the first two steaks cooked to ensure the equipment was functioning as expected. After this confirmation, the loin steaks were cooked to the required time and no further product temperatures monitored. The grilling and resting times were measured with digital timers.

Once the steaks had been grilled for the required amount of time, they were removed from the grill and placed next to their ID label on the cutting board for resting. After two minutes resting on the cutting board, two steaks (grilled at the same time) were trimmed on all four sides to remove fat and edges and the centre piece used for consumer evaluation. This was transferred with its label to a Pyrex holding container. One steak piece was placed in an individual container. This process was repeated for the eight steaks required for each sensory session.. Between each sensory session, the grill was switched off and the plates thoroughly cleaned with hot water and detergent.

<u>Stir Fry</u>
The two woks used in this study were Sunbeam electric woks Model WW4500D (Sunbeam, Locked Bag 5041, Botany, NSW, Aus). Approximately 30 minutes before the start of the sensory session both woks were pre-heated to setting Number 7. A tablespoon (approximately 5 g) of rice bran oil was added to Wok 1 and pre-heated for 30 seconds before one batch (15 pieces) of stir fry was cooked, turned every 15-20 seconds for even colour development during cooking. Due to the short resting time after stir frying to achieve the required final endpoint temperature, all batches of stir fry were continuously monitored for temperature throughout the cooking and resting periods; with a k-type thermocouple attached to a digital thermometer.

Once the first batch of stir fry was cooked to the required final endpoint temperature it was removed from the wok and placed into a labelled Pyrex holding container. Oil was added to Wok 2, pre-heated and the next batch of stir fry pieces cooked whilst the first wok was wiped out with a paper towel and prepared for the next batch of stir fry pieces. This procedure continued until the six stir fry batches had been completed for the session. In between the sensory sessions, the woks were switched off and thoroughly cleaned with hot water and detergent.

The grilling and stir frying was undertaken by two people in parallel to minimise the holding time of samples prior to consumer evaluation.

2.1.3.5 Presentation Protocols

The kitchen/preparation room was maintained at a temperature of 23°C during the sensory sessions. In each session, the samples (n=7) evaluated by each consumer (n=8) were in a randomised tasting order so the samples (n=56) needed to be prepared and ready to serve for the start of the sample evaluation section of the sensory session; approximately 10 minutes after the start of the session. The samples could not be prepared to order. Some samples were stored in the containers for up to 35 minutes prior to consumer evaluation.

To keep the prepared samples warm during the evaluation and prevent moisture loss they were stored in sealed and labelled glass Pyrex containers (World Kitchen, Rosemont, Illinois, USA) on top of heated warming plates (n=4) from Cuisinart Model CWT-240A (Cuisinart Australia, 24, Salisbury Road, Asquith, NSW, Aus). At the start of the day, the warming plates were preheated to the 65°C setting and the Pyrex containers (n=20) placed on top. A duplicate set of Pyrex containers was available so these could be placed on the warming trays to pre-heat for the next sensory session whilst the soiled ones were cleaned.

<u>Roast</u>
The roast pieces were prepared once the stir fried samples had been cooked and each roast piece (n=6) was prepared in the same way. The roast and its ID label were transferred from the resting bench to a cutting board and the temperature probe removed after an identification check between the label on the roasting tray and digital thermometer.
The roast pieces were prepared as follows:

1) the rind and all visible fat were removed;
2) the piece was cut in half along the grain of the meat;
3) the cut flat surface was turned down onto the cutting board surface;
4) both half pieces were cut into 6 mm ±1 mm thick slices across the grain; and
5) all slices were placed into a Pyrex holding container and labelled.

A total of 18–24 slices were obtained from each roast piece with 12 slices required for each sensory session.

2.1.3.6 Serving of Samples to Consumers

A one page serving order document was prepared for all 320 consumers in the study. This document contained the order in which the seven samples were to be tasted (identified by order, sample description and 4 digit identification number) by each panelist in each session. Before the start of each session, the page corresponding to the correct session and panelist was secured above the booth for each consumer in the kitchen/preparation room. The seven sample plates were also pre-labeled with the 4 digit sample numbers and stacked in the correct tasting order by the booth.

The consumers were instructed to switch on a light once they were ready to evaluate a sample of pork. This action illuminated a duplicate light in the kitchen/preparation room which served as a signal to commence the serving process to that consumer. Two people undertook the serving of samples in a sensory session; one person responsible for serving Panelists 1-4 and the other for Panelists 5-8.

When a consumer was ready for a sample and the light was illuminated, the server would identify the panelist and sample number required. They would:

1) switch off the light to indicate the sample was being prepared;
2) collect pre-labeled sample plate from beside the tasting booth
3) locate the correct sample in the Pyrex container;
4) undertake a number identification check between plate and Pyrex container;
5) place sample onto the plate;
6) open the serving hatch and present the sample to the consumer; and
7) cross out the sample ID number on the serving order document.

This process was repeated for all seven samples and the protocol followed for all sensory sessions. The serving operation was completed in approximately 30 to 35 minutes per session.

The serving sizes for each cooking method were:

1) Roast: three slices
2) Grill: steak centre piece
3) Stir Fry: three pieces.

2.1.3.7 Consumer Evaluation

In each sensory session (n=40), eight consumers evaluated seven pork samples (56 tastings) with each primal cut per treatment (n=7) being assessed by four consumers in a session. The eight consumers registered at the start of each session were given a short briefing on the sensory evaluation process and then taken to the sensory evaluation room and placed in the eight individual tasting booths to start the session.

Panelists recorded assessments by touch screen through the use of a computerised sensory evaluation program, Compusense Five version 5.2 (6/9 Southgate Drive, Guelph, Ontario, Canada).

The session commenced with consumers answering a number of questions to capture individual demographic information which included: gender, household size, age, current purchasing, cooking and consumption habits of fresh pork. Consumers were then presented with each pork sample for evaluation on a numbered plastic plate as per the serving protocol described above. They were first asked to enter the 4 digit identification number for the sample, smell it and rate the sample for aroma. They were then asked to eat most of the sample before scoring for tenderness, juiciness, flavour and overall liking.

Consumers assessed the eating quality attributes of the pork samples using a continuous line scale as per Australian Standard for Sensory Analysis (2007). This method provided panelists with an opportunity to express small differences in judgment as they marked the line in the position corresponding to perceived intensity for that attribute. Although potentially a more difficult task for the consumer than using a category scale, the line scale permits unlimited fineness of differentiation among consumer assessments. To ensure that the scale was easily understood by panelists, the word anchors were carefully selected for each attribute and prior to the evaluation of pork samples, consumers completed a number of line scale practice assessments.

The continuous line scales used for the five quality attributes were anchored at each end with words with right hand side equivalent to 100 and left hand side equivalent to 0. Numerical intensity values were not shown to the consumers:

1) Aroma liking: Dislike extremely to like extremely.
2) Tenderness: Not tender to Very tender
3) Juiciness: Not juicy to Very juicy
4) Flavour liking: Dislike extremely to Like extremely
5) Overall liking: Dislike extremely to Like extremely

Each consumer also graded the samples for quality into one of the following categories:

1) Unsatisfactory (this was terrible, I did not enjoy it all)
2) Below average (this was not nice, I did not enjoy it)
3) Average (this pork was nice, I somewhat enjoyed it)
4) Above average (this pork was really nice, I enjoyed it)
5) Excellent (this pork was excellent, I really enjoyed it)

Each sample was also rated for repurchase intention into one of the following categories:

1) I definitely would not buy it
2) I would probably not buy it
3) I might buy it
4) I would probably buy it
5) I would definitely buy it

Consumer assessment progress was monitored remotely on the laptop running the computerised program and assistance was provided when required. Consumers could not move onto the next question or assessment until the previous answer or assessment was completed. The session was completed once all consumers had assessed and rated their seven samples.

2.1.4 Statistical analysis

2.1.4.1 Animal performance and objective meat quality analysis

An analysis of variance was conducted using Genstat 13.1 (VSN International, 2010) to determine the effect of gender on growth performance and carcase attributes and the effect of gender, ageing period and endpoint temperature and their interactions on objective meat quality attributes. A blocking structure of day of slaughter was used in the ANOVA for growth performance, carcase measurements, androstenone and skatole levels and meat quality measures of muscle pH, meat colour, drip loss and intramuscular fat. The analysis of variance for Warner-Bratzler shear force and cooking loss included a blocking structure of block within day to account for the allocation of sides to the ageing period x endpoint temperature treatments.

Correlation analysis to determine relationships between objective and sensory measurements were conducted using Genstat 15.2 (VSN International, 2012).

2.1.4.2 Sensory analysis

An analysis of variance was conducted to determine the effect of treatment factors and their interactions on sensory attributes of pork using R (R version 2.14.0, http://www.r-project.org).

A total of 56 treatment combinations were involved in this 2x2x2x7 factorial designed study - gender (2 levels), ageing period (2 levels), endpoint temperature (2 levels) and cut x cooking method (7 levels). For the sensory analysis, two pigs per gender treatment were divided into two pairs. Each pair provided four sides, allocated to one of four combinations of ageing (2 or 7 d post-slaughter) and internal temperature (70 or 75°C) in one of three different ways. The allocation of pigs and sides within pigs to a session is shown is Table 3. As there were 10 pairs for each gender, these three treatment allocations to carcase pairs could not be done equally often - in each case two of them were done four times and the other done twice. Each case provided 3 degrees of freedom.

Table 3: Allocation of pigs and sides within pigs to ageing and final endpoint temperature treatment

Case		i		ii		iii	
	Pig	1	2	1	2	1	2
Side	1	2d, 70°C	7d, 70°C	2d, 70°C	7d, 70°C	2d, 70°C	7d, 70°C
	2	7d, 75°C	2d, 75°C	2d, 75°C	7d, 75°C	2d, 75°C	7d, 75°C

With 40 pigs, 2 sides and 7 packs per side, there were a total of 560 packs. The seven packs consisted of different cuts of meat to which different cooking methods were applied (Table 4). Each pack was further subdivided into 4 samples for consumer evaluation, a total of 560 x 4=2240 samples were tasted. Each consumer tasted 7 samples in a session, so 320 consumers were required. A total of 40 sessions were held, each involving 8 consumers.

Table 4: Cuts and cooking methods evaluated in this study

Sample	1	2	3	4	5	6	7
Cut	Shoulder (blade)	Shoulder (chuck tender)	Loin	Loin	Loin	Silverside	Silverside
Cooking method	Roast	Stir fry	Roast	Stir fry	Steak	Roast	Stir fry

For each cut obtained from each side of the carcase, four samples were obtained, providing 28 samples per side. Two sides provided the 56 samples required for each session. Table 5 details the design used to allocate samples to consumers within a session, with the letters A and B denoting the two sides used.

Table 5: Allocation of samples to consumers within a tasting session

Sample	Consumer							
	1	2	3	4	5	6	7	8
Shoulder Stir fry	1A	1B	1A	1B	1A	1B	1A	1B
Silverside Roast	2A	2B	2A	2B	2B	2A	2B	2A
Silverside Stir fry	3A	3B	3A	3A	3A	3B	3B	3A
Shoulder Roast	4A	4B	4A	4A	4B	4A	4A	4B
Loin Stir fry	5A	5A	5B	5B	5A	5A	5B	5B
Loin Steak	6A	6A	6B	6B	6B	6B	6A	6A
Loin Roast	7A	7A	7A	7A	7B	7B	7B	7B

Within a session, the two sides had the same endpoint temperature to minimize potential risks of error and thus had different levels of ageing period. As shown in Table 3 cases (i) and (ii) involved taking sides from two different pigs, where case (iii) required two sides from the same pig. Each consumer saw all seven cooking methods, but either (i) saw all seven samples of the same ageing period if consumer 1, or (ii) saw three from one ageing period and four from the other ageing period if consumer 2-8. Ageing period and (cut x cooking method) was therefore partially confounded with consumers. As consumers were presented with their seven samples in order, it was imperative that they were not all given the cut x cooking method samples in the same order. A Latin Square was used to ensure each of the cut x cooking method combinations occurred once at each order. As there were eight consumers and seven cut x cooking methods in each session, one cut x cooking method occurred twice at each order.

A formal analysis of variance was developed for this complex design. Three versions of this were conducted. The first of these considered an analysis of the 80 means corresponding to the 80 sides (40 pigs x 2 sides). The second was an analysis of the 1120 observations for 20 pigs corresponding to pigs of one gender, while the third included the two gender groups and provided expected mean squares for each of the variance terms (n=2240 observations).

A number of sources of variability were taken into account in this analysis. Each of the 56 treatment combinations occurred in the design 40 times. Cooking effects were handled in the analysis as a 2 x 3 (cooking method (roast or stir fry) x cut (shoulder, loin or silverside)) factorial + 1 (loin steak). The appropriate standard errors for doing statistical tests/comparisons between the treatments were considered, however, this was complicated by the many sources of variability in this study. It was thought that pigs, even within the same gender, would differ from one another, however, the two sides within the same pig were not considered to differ as much, but differences between the packs within a side were expected as they were sourced from different primals.

Furthermore, relatively small differences between the four samples within each cut x cooking method combination were expected. However, variability between sessions was expected due to each session involving different consumers as well as potential differences in preparing and serving samples to panelists. Variability between consumers was also expected as consumers were untrained.

As a result of these different sources of variability, components of the treatments occurred with different accuracy in different levels of the analysis. As each pair of sessions contained two pigs of the same gender, gender was applied to different sessions. The appropriate error to test for gender differences was a 'between session' variance. As samples within each session were cooked to the same level of final endpoint temperature, the effect of temperature was also estimated as a 'between session' variance. These two factors were estimated with less accuracy than ageing period and (cut x cooking method).

The effect of order of presentation of samples to consumers was addressed using analysis of variance. This analysis identified that 75% of the information on order effects was contained in the "within packs and consumers" stratum, about 20% in the "between packs" stratum and another 5% in the other strata.

The constraints applied were:

- Each session used 2 sides, providing 56 samples.
- Each session used pork from a single gender. This was done to minimize any risk associated with boar taint from the entire male pigs affecting consumer assessment of samples from immunocastrates.
- A secondary constraint related to the cooking methods; each session was done at a single level of endpoint temperature to minimize errors.
- Pairs of carcases were used in a session. The two sessions were then created by taking the two sides which had the same temperature. In cases (i) and (ii) above, the two sides came from different pigs, while in case (iii), the two sides came from the same pig.
- Each pair of sessions contained two pigs of the same gender, so gender was always "applied" to different sessions. The appropriate error for testing gender differences was the "between session" variance. Also, as each session was conducted at the same level of temperature, the effect of endpoint temperature was estimated between sessions. Therefore, gender and endpoint temperature was estimated with less accuracy than ageing period and cut x cooking method.

The components of the analysis of variance (degrees of freedom, efficiency for treatments) are shown in Table 6.

Table 6: Components of the analysis of variance (degrees of freedom, efficiency for treatments) used in this study

	Blocks	Session	Consumers	Samples	Total
Gender	1				
Gender:Temp	2 (0.3)				
Gender:Age			2 (0.043)	2 (0.257)	
Gender:Age:Temp			2 (0.057)	2 (0.343)	
Residual	22		10	10	
Pigs	25		14	14	
Gender:Temp		2 (0.7)			
Gender:Age			2 (0.1)	2 (0.6)	
Gender:Age:Temp			2 (0.086)	2 (0.514)	
Residual		12	22	22	
Sides within pigs	0	14	26	26	
Gender:Age:Cooking†			12 (0.143)	12 (0.857)	
Gender:Age:Temp:Cooking			12 (0.143)	12 (0.857)	
Residual			216	216	
Gender:Cooking				12 (1)	
Gender:Temp:Cooking				12 (1)	
Residual				216	
Packs within sides	0	0	240	480	
Samples within packs				1400	
Total	25	14	280	1920	2239

†Cooking refers to cut type x cooking method interaction

Table 7 details the blocks (pairs of carcases and pairs of sessions) that were allocated to each case and treatment levels that were confounded with this design.

Table 7: Allocation of pigs and sides within pigs to ageing and final endpoint temperature treatment and treatment levels (A – ageing period, T – temperature) that were confounded due to the design used

Case		I		ii		iii	
	Pig	1	2	1	2	1	2
Side	1	2d, 70°C	7d, 70°C	2d, 70°C	7d, 70°C	2d, 70°C	7d, 70°C
	2	7d, 75°C	2d, 75°C	2d, 75°C	7d, 75°C	2d, 75°C	7d, 75°C
Blocks - gender							
Entire males		1,4,5,14		3,11,15		2,12,13	
Immunocastrates		10,16,17,18		8,9,19		6,7,20	
Confounded							
With sessions		T		T		T	
With pigs		AT		A		T	
Not confounded		A		AT		A, AT	

Regression analysis was used to predict overall liking of pork based on the four attributes of tenderness, aroma, juiciness and flavour. Regression analysis was also used to determine whether quality grading score and re-purchase intention could be predicted from sensory variables assessed in this study. Chi-square analysis was used to determine treatment differences for fail rate for both quality grade and re-purchase intention.

3 Outcomes

3.1 Effect of gender, ageing period, muscle, cut type and endpoint temperature

3.1.1 Objective measurements

No differences in liveweight recorded at birth, weaning and at the commencement of the grower and finisher stages were found between immunocastrated and entire male pigs (Table 8). Immunocastrated males were heavier (P=0.037) than entire male pigs when weighed one day prior to slaughter. Average daily gain, from both birth to finisher and during the finisher phase, was higher for immunocastrates than entire males (P<0.05), but no effect of gender was found for average daily gain during the grower phase as anticipated. Entire male carcases were leaner at the P2 site (P<0.001), increased muscle depth at the P2 site (P=0.013) and had a 2.2% higher (P=0.009) dressing percentage than immunocastrates. No differences were found between genders for hot carcase weight (HCW) or cold carcase weight (CCW), indicating that organ weights may have been higher for immunocastrates compared with entire males.

The administration of Improvac at 10 and 15 weeks to males allocated to the immunocastration treatment was effective, with lower androstenone (P<0.001) and skatole (P=0.025) levels in immunocastrates than entire male pigs. Overall, five entire males (25%) had androstenone levels > 1µ/g and of these, two were categorized to have boar taint (androstenone > 1µg/g and skatole > 0.2µg/g). Androstenone levels of immunocastrated males were all below the lower limit of quantification (<0.2 µg/g) and analysed as 0.1 µg/g.

Table 8 Predicted means and standard error of the difference (s.e.d) for effect of gender on liveweight at various stages of growth, average daily gain and carcase parameters

	Entire male	Immunocastrated male	s.e.d.	P value
Birth weight (kg)	1.58	1.60	0.093	0.766
Weaning weight (kg)	6.02	5.77	0.444	0.569
Weaner - grower weight (kg)	25.8	24.6	1.25	0.365
Grower- finisher weight	52.2	51.2	2.12	0.623
Full final liveweight (kg)	92.8	96.9	1.883	0.037
ADG (kg/day)				
Finisher phase	0.967	1.089	0.034	0.002
Grower phase	0.756	0.758	0.033	0.935
Birth to finisher	0.626	0.654	0.013	0.035
P2 fat depth (mm)	9.4	11.5	0.56	<0.001
HCW (kg)	72.4	73.4	1.53	0.546
Estimated Trim 13 HSCW (kg)	65.9	66.7	1.39	0.546
Muscle depth (mm)	59.1	57.9	0.46	0.013
Dressing percentage (%)*	78.4	76.2	0.79	0.009
Chilling loss (%)	5.43	4.39	0.740	0.169
Cold carcase weight (kg)	62.3	63.8	1.48	0.327
Androstenone (µg/g)	0.631	0.100	0.120	<0.001
Skatole (µg/g)	0.116	0.039	0.033	0.025

* Only carcases with no additional trim removed prior to the scales were included for dressing percentage

Gender did not influence muscle pH of the loin measured from 45 min to 6 hours post-slaughter, however muscle pH at 24 hours was 0.15 pH units higher in immunocastrates compared with entire males. No differences due to gender were found for muscle temperature measured from 45 min to 24 h post- (Table 9). When adjusted for P2 fat depth, only temperature at 45 min was influenced by gender of the pig.

Table 9: Predicted means and standard error of the difference (s.e.d) for effect of gender on muscle pH and temperature measured in the *M. longissimus thoracis* from 45 min to 24 h post-slaughter

	Entire male	Immunocastrated male	s.e.d.	P value	P value covariate
pH					
45 min	6.37	6.50	0.075	0.077	
90 min	6.28	6.40	0.076	0.144	
3 hours	6.25	6.37	0.078	0.112	
6 hours	6.03	6.03	0.077	0.917	
24 hours	5.81	5.96	0.073	0.047	
Temperature					
45 min	34.07	35.12	0.694	0.141	
90 min	23.38	24.02	0.811	0.431	
3 hours	15.67	15.95	0.629	0.659	
6 hours	7.66	8.32	0.548	0.236	
24 hours	2.75	2.67	0.051	0.106	
Means adjusted to a P2 fat depth of 10.45 mm, and s.e.d.					
Temperature					
45 min	35.65	33.53	0.756	0.008	0.011
90 min	23.98	23.42	0.891	0.531	0.015
3 hours	16.30	15.32	0.640	0.138	<0.001
6 hours	8.36	7.62	0.484	0.134	<0.001
24 hours	2.75	2.67	0.061	0.214	0.817

Only the main effect of gender influenced muscle pH of the silverside when measured at both 2 and 7 days post-slaughter; entire males produced silversides with a higher pH (P=0.048) than immunocastrates. Ageing for 7 d post-slaughter reduced (P<0.001) muscle pH of the chuck tender by 0.31 units compared with ageing for 2 d post-slaughter. In contrast, muscle pH of the blade increased (P<0.001) by 0.20 units when aged for 7 days compared with 2 days.

Only ageing period influenced muscle lightness (L* value), redness (a* value) and yellowness (b* value) of the loin muscle (Table 10). For the silverside, ageing for 7 days increased muscle lightness (P<0.001) and yellowness (P<0.001), but not redness compared with ageing for 2 days post-slaughter. Silversides and blade muscles from immunocastrates was paler (P=0.032; higher lightness values) than those from entire male pigs. In contrast, for the blade, ageing for 7 days reduced muscle lightness (P=0.021) compared with ageing for 2 days. Both redness (P<0.001) and yellowness (P<0.001) increased for the blade and only redness (P<0.001) of chuck tender when aged for 7 days than for 2 days post-slaughter.

For the loin only, ageing for 7 days reduced (P=0.004) drip loss of pork compared to ageing for 2 days. Drip loss of the silverside was not influenced by gender or ageing period.

Pork from immunocastrates had a higher (P<0.001) content of intramuscular fat in the loin than entire males (3.16% and 1.68%, respectively). Overall, intramuscular fat levels of the loin ranged from 0.4 to 5.9%. Higher (P<0.001) levels of intramuscular fat were also found for the silverside and blade from immunocastrated males compared with entire males.

Table 10: Predicted means and standard error of the difference (s.e.d) for effect of gender (S) and ageing period (AP) on muscle pH and meat colour (L*, a*, b*) of the loin (*M. longissimus thoracis*), silverside (*M. biceps femoris*), blade *(M. triceps brachii*) and chuck tender (*M. supraspinatus*),

	Entire male		Immunocastrated male		s.e.d.	P value		
	2 d	7 d	2 d	7 d		S	AP	SxAP
Loin								
pH	5.42	5.46	5.46	5.48	0.024	0.076	0.14	0.68
L	50.99	52.28	51.58	52.73	0.585	0.21	0.004	0.87
a	5.51	6.35	5.59	6.11	0.280	0.66	<0.001	0.42
b	2.00	2.94	2.34	2.99	0.192	0.15	<0.001	0.27
Drip loss	3.99	2.99	3.88	2.80	0.780	0.64	0.010	0.42
IMF %	1.68		3.16		0.216	<0.001		
Silverside								
pH	5.52	5.54	5.45	5.51	0.037	0.048	0.14	0.56
L	46.15	46.85	46.71	48.86	0.833	0.032	0.018	0.22
a	9.58	9.63	9.15	9.88	0.443	0.77	0.22	0.28
b	3.10	4.81	3.02	5.73	0.365	0.11	<0.001	0.057
Drip loss	2.38	1.74	2.18	2.10	0.33	0.72	0.13	0.23
IMF %	1.15		2.04		0.290	<0.001	0.39	0.053
Blade								
pH	5.80	6.04	5.74	5.91	0.069	0.066	<0.001	0.43
L	43.69	41.69	44.60	43.65	0.883	0.025	0.021	0.40
a	12.27	16.44	12.32	16.05	0.563	0.67	<0.001	0.58
b	2.90	5.06	3.32	5.86	0.361	0.020	<0.001	0.47
IMF%	1.02		1.70		0.137	<0.001		
Chuck tender								
pH	6.12	5.75	6.03	5.77	0.058	0.40	<0.001	0.22
L	42.18	43.24	43.43	43.53	0.838	0.20	0.33	0.42
a	16.11	12.77	14.87	13.39	0.590	0.46	<0.001	0.029
b	4.58	3.68	4.27	4.21	0.388	0.70	0.082	0.13

WBSF values were not influenced by gender or ageing period. Cooking pork to a final endpoint temperature of 75°C, rather than to 70°C, increased WBSF values for the loin (3.89 vs. 3.47 kg, respectively; s.e.d. 0.195, P=0.036) but not for the silverside (Table 11). However, cooking pork to a final endpoint temperature of 75°C, rather than to 70°C, increased cooking loss from the loin by 8.9% (27.1 vs. 18.2%, respectively; s.e.d. 0.443;

P<0.001) and by 1.25% for the silverside (28.9 vs. 27.7%, respectively; s.e.d. 0.646; P=0.058).

Table 11: Predicted means and standard error of the difference (s.e.d) for effect of gender (S), ageing period and endpoint temperature on Warner-Bratzler shear force (kg) and cooking loss from the loin and silverside muscles

	Entire male				Immunocastrated male				s.e.d.	P value			
	2d		7d		2d		7d			S	AP	T	Interactions
	70°C	75°C	70°C	75°C	70°C	75°C	70°C	75°C					
WBSF (kg)													
Loin	3.67	4.41	3.39	3.79	3.74	3.52	3.08	3.83	0.389	0.17	0.11	0.036	S*AP*T (P= 0.095)
Silverside	3.17	3.27	2.86	2.84	2.87	2.79	2.68	2.98	0.298	0.18	0.21	0.61	
Cooking loss (%)													
Loin	19.06	27.56	19.67	27.62	17.23	27.33	18.92	27.89	0.880	0.15	0.10	<0.001	
Silverside	26.43	29.41	29.16	27.63	26.82	29.32	28.35	29.39	1.292	0.63	0.33	0.058	AP*T (P=0.024)

3.1.2 Demographic data

In this study, 41.8% of consumers were male and 58.1% were female (n=320). The average household size was 2.94±1.33 persons. The distribution in ages of consumers involved, according to gender, is shown in Table 12.

Table 12: Distribution of males and females involved in this study within each age group

	18-25 years	26-30 years	31-40 years	41-50 years	51-60 years	61-65 years
Male	7.5	3.1	4.7	7.2	10	8.4
Female	8.8	4.1	9.7	15	12.8	7.8
Total	16.3	7.2	14.3	22.2	23.8	16.3

Overall, 42.2% of consumers in this study responded that they ate fresh pork (not including ham, bacon or salami) at least weekly (Table 13).

Table 13: Pork consumption frequency of consumers involved in this study

4-5 times per week	1.6
2-3 times per week	23.4
Weekly	42.2
Fortnightly	18.8
Monthly	14.0

The consumption frequency of meat meals, including pork, is detailed in Table 14.

Table 14: Frequency of consumption of pork, beef, lamb, chicken and fish (other than mince or sausages) in the last week by consumers who participated in this study

	Number of meals in the last week				
	1	2	3	4	5
Pork	43.1	27.2	12.5	1.3	0.3
Beef	35.0	34.7	10.9	0.6	0.9
Lamb	42.5	20.6	5.0	0.9	0
Chicken	23.8	37.8	21.6	6.9	3.1
Fish	44.3	20.0	5.3	1.3	0

Pork rated highly in terms of its appeal, second only to chicken and higher than beef, by consumers involved in this study (Table 15). However, fewer consumers rated pork as either an 8, 9 or 10 for appeal and it ranked fourth in this category.

Table 15: Consumer appeal of chicken, pork, beef, lamb and fish, taking into consideration what they liked to eat, prepare and cook (0 – not at all appealing to 10 – extremely appealing).

	Appeal score			Average±
	0-4	5-7	8-10	SD
Chicken	15.0	56.3	28.8	7.25±1.91
Pork	20.3	65.6	14.1	6.78±1.67
Beef	24.4	62.8	12.8	6.46±1.97
Lamb	26.3	54.7	19.0	6.31±2.23
Fish	31.9	48.8	19.4	6.03±2.47

The major cuts of pork purchased by consumers involved in the sensory panels were pork loin chops/cutlets (63%), roasting cuts (60%), rashers/spare ribs (43.1%), fillets (40.3), sausages (40%),mince (33.4%), diced/stir fry (26.9%), steaks (26.6%) and schnitzels (16.3%).

Consumer preference for cooking pork to ‘medium rare, pink’, ‘medium, hint of pink’, ‘medium/ well done, white’ and ‘well done’ was 5.0%, 41.6%, 40% and 13.4%, respectively. Grilling/BBQ/pan frying was the most popular cooking method used by consumers involved in this study (79.4%), followed by roasting (64.4%), stir frying (52.8%) and casserole/simmer (11.3%).

3.1.3 Sensory results

Summary statistics across all treatments for sensory attributes of pork are presented in Table 16. Some consumers scored samples either 0 or 100 on the scale used in this study for all attributes and further analysis of data excluding these consumers may be required.

Table 16: Summary data for sensory attributes of cooked pork aroma, tenderness, juiciness, flavour and overall liking of pork and scores for quality grade and re-purchase intention (n=2240)

	Minimum	1st quartile	Median	Mean	SD	3rd quartile	Maximum
Aroma	0.5	47.0	64.5	62.37	22.18	80.5	100
Tenderness	0.0	39.4	62.5	59.41	26.60	81.5	100
Juiciness	0.0	41.5	62.5	60.03	25.27	81.0	100
Flavour	0.0	46.0	65.5	62.21	23.33	80.5	100
Overall liking	0.0	45.0	64.5	61.73	23.86	80.5	100
Quality grade	0.0	3	3	3.43	0.98	4	5
Repurchase intention	0.0	3	4	3.46	1.22	5	5

The correlation coefficients between sensory attributes for all consumer tastings are shown in Table 17. Flavour and overall liking were most highly correlated and aroma least correlated with the other four attributes.

Table 17: Correlation coefficients between sensory attributes for all consumer tastings (n=3360)

	Aroma	Tenderness	Juiciness	Flavour	Overall liking
Aroma	1.000				
Tenderness	0.361	1.000			
Juiciness	0.417	0.826	1.000		
Flavour	0.549	0.722	0.756	1.000	
Overall liking	0.498	0.830	0.834	0.913	1.000

The correlations between the sensory attributes evaluated in this study across consumers are shown in Table 18. Overall, the highest correlation was found between flavour and overall liking.

Table 18: Correlation coefficients between sensory attributes across consumers (n=480)

	Aroma	Tenderness	Juiciness	Flavour	Overall liking
Aroma	1.000				
Tenderness	0.648	1.000			
Juiciness	0.669	0.881	1.000		
Flavour	0.741	0.793	0.830	1.000	
Overall liking	0.714	0.867	0.880	0.943	1.000

Overall liking of pork was influenced, in order of importance, by flavour, tenderness and juiciness.

Overall liking= -0.013 + 0.610xFlavour + 0.235xTenderness+ 0.155xJuiciness (R^2=0.90).
All coefficients were statistically significant (P<0.001), except aroma (P=0.287)

Consumer responses for quality grade score and re-purchase intention are shown in Table 19 (n=2,240 evaluations). Scores for quality grade score were slightly higher than for re-purchase intention.

Table 19: Matrix of panelist scores received for quality grade and re-purchase intention

Quality grade score	Re-purchase intention 1	2	3	4	5	Total
1	44	3	1	0	0	48
2	100	210	16	1	0	327
3	0	170	496	166	1	833
4	2	4	41	411	223	681
5	0	0	0	13	338	351
Total	146	387	554	591	562	

Linear regression analysis of quality grade score with the five sensory attributes assessed in this study identified that overall liking was the most important variable influencing quality grade score. The equation was:

Quality grade score = 1.369 – 0.003 x Aroma + 0.003xTenderness + 0.005xFlavour + 0.029xOverall liking

The regression equation for prediction of quality grade score with overall liking was:

Quality grade score = 1.31 + 0.034xOverall liking (SD 0.56, R^2 0.63)

The relationship between re-purchase intention and the sensory attributes assessed, with only significant ($P<0.05$) terms included, was:

Re-purchase intention = 0.964 – 0.002xAroma + 0.003 x Tenderness – 0.003xJuiciness + 0.040 x Overall liking

Flavour was not significant (P=0.148).

A regression analysis was then conducted with overall liking in the analysis:

Re-purchase intention = 0.89 + 0.042 x Overall liking (SD 0.7, R^2 0.54)

The main effect of gender did not influence sensory attributes of pork (Table 20).

Table 20: Effect of gender, across all other treatment combinations, on eating quality attributes of pork

	Entire male	Immunocastrate	s.e.d.	P value
Aroma	62.5	62.2	1.69	0.880
Tenderness	59.1	59.7	1.96	0.746
Juiciness	59.5	60.6	2.18	0.613
Flavour	62.4	62.0	1.98	0.861
Overall liking	61.5	61.9	1.92	0.840
Quality grade	3.40	3.45	0.061	0.437
Re-purchase intention	3.43	3.49	0.071	0.386

The main effects of gender, ageing period, cut type or endpoint temperature were not significant for aroma (Table 21), with differences only found for cooking between roasts and stir fry. Overall, aroma scores for roasts were 10.8 units lower (P<0.0001) than stir-fry across the three primals. The interaction between temperature and cooking method (roast or stir fry) (P=0.019) resulted in lower aroma scores of roasts cooked to 75°C compared to 70°C, whilst for stir fry cooking to 75°C increased aroma scores compared to cooking to 70°C. In addition, the interaction between ageing period and cooking method (roast or stir fry) (P=0.022) reduced aroma scores of 7d aged roasts compared with 2 d aged roasts and aroma scores of 7d aged stir fry were higher than 2 d aged stir fry.

Gender, ageing period and endpoint temperature did not influence consumer scores for tenderness (Table 22). Cooking influenced tenderness and when separated into its factorial components, differences due to cooking were found between cuts, steaks and all other cuts (P<0.00001) and for the interaction between cut type and cooking method (roast or stir fry) (P<0.0001). Tenderness varied across the three primals in this study (P<0.0001), with tenderness scores for shoulder cuts found to be 16 and 25 units higher than loin and silverside, respectively (74.48, 58.57 and 49.61, respectively). Loin steaks obtained similar scores for tenderness to silverside cuts, but lower than those obtained for roast and stir fry cuts from shoulder and loin. When compared to the average of all other cuts, tenderness scores for loin steaks were 10.3 units lower. The significant cut x cooking method interaction for tenderness results from higher tenderness scores for shoulder stir fry compared to shoulder roasts, whilst tenderness scores for roasts from loin and silversides were higher than for stir fry. The interaction between ageing period and cooking method was also significant (P=0.011); tenderness scores for 7 d aged stir fry were 4.5 units lower than 2 d aged stir fry with no difference due to ageing for roasts.

Cooking was the main factor influencing juiciness - no effects of gender, ageing period or interactions with gender were found (Table 23). There was a tendency (P=0.092) for juiciness scores to be influenced by endpoint temperature (61.7 and 58.4 for pork cooked to 70 and 75°C, respectively, s.e.d. 1.291). When cooking was separated into its factorial components, differences between steaks and all other cuts (P<0.0001), between roasts and stir fry (P=0.0025), cut type (P<0.0001) and cut type x cooking method (P=0.001) influenced juiciness scores. Juiciness scores for the shoulder cuts were 14.9 and 19.4 higher than the mean score for loin and silverside (roasts and stir fry only), respectively. Loin steaks were less juicy when compared to the average juiciness score for all of the other cuts evaluated (53.40 vs. 61.13, respectively; P<0.0001). Pork from the shoulder cooked as stir fry obtained juiciness scores 9.1 units higher than roasts, with little difference between roast and stir fry for the other two cuts. The interaction between endpoint temperature and loin steak was also significant (P=0.043); juiciness scores declined by 4.98 units when endpoint temperature was increased from 70 to 75°C (55.89 vs. 50.91, respectively), but did not influence juiciness of the other cuts.

As found for juiciness, no effects of gender, ageing period or interactions with gender were found for flavour (Table 24). Cooking influenced flavour and these cooking effects were between steaks and all other cuts (P<0.0001), between roast and stir fry (P=0.0001) and cut type (P<0.0001). Flavour scores for the shoulder were higher than those for the loin, silverside and loin steak, by 9.5, 13.2 and 13.7 units, respectively. Average flavour scores for roasts were 3.6 units (P=0.0001) lower than for stir fry. The flavour of loin steaks were 6.1 units lower (P<0.0001) than the average flavour scores of all other cuts assessed in this study (59.98 vs. 63.08, respectively). The interaction between ageing period and cooking method (roast vs. stir fry) was also significant (P=0.027), where flavour scores for roasts not influenced by ageing for 7d, but flavour scores of 7d aged stir fry were higher than those aged for 2d post-slaughter. Inconsistent effects of endpoint temperature on flavour across cuts were found – flavour of loin cuts decreased as temperature increased from 70 to 75°C, whilst those for the shoulder cuts increased.

The main effects of ageing period (P=0.034) and cooking (P<0.0001) influenced overall liking of pork in this study (Table 25). Pork aged for 7d post-slaughter scored an average of 2.9 units higher than 2 d aged product, across all treatment combinations. No interactions with gender for overall liking were significant. Cooking effects were due to cooking method (roast and stir fry; P=0.0006), between steaks and all other cuts (P<0.0001), cut type (P<0.0001) and the interaction between cooking method and cut type (P<0.0001). Overall liking scores of loin steaks were 7.7 units lower than the average score of the other cut x cooking method combinations (55.10 vs. 62.84, respectively). Shoulder stir fry obtained higher (P<0.0001) overall liking scores than shoulder roast, accounting for the cut x cooking method interaction. The interaction between endpoint temperature and cut type was found (P=0.007); lower overall liking scores were obtained for the loin when cooked to 75°C than 70°C, with the converse effect of endpoint temperature for the shoulder. Stir fry aged for 7 d had higher (P=0.0049) overall liking scores than that aged for 2 d, whilst for roasts, ageing for 7 d reduced overall liking scores compared with 2 d aged roasts.

Cooking was the only main effect found to influence quality grade of pork (P<0.0001) (Table 26). Differences between cut type (P<0.0001), cooking method (P=0.0014) and cut x cooking method (P=0.0025) were found. Quality grade scores were 0.15 units higher for stir fry than for roasts. Overall, higher quality grade scores were obtained from cuts from the shoulder than roast and stir fry cuts from the loin followed by loin steaks and silverside stir fry, and lastly, silverside roasts. Quality grade scores of loin steaks were 0.28 units lower than the average score of the other cut x cooking method combinations (3.18 vs. 3.47, respectively). The significant ageing period x cooking method interaction was due to a 0.30 unit decline in quality grade scores when roasts were aged for 7d compared with 2 d, with only a small decline of 0.08 units found for stir fry due to ageing for 7 d. The interaction between ageing period, temperature and cut type was significant for quality grade and were due to the high scores for shoulder stir fry aged for 7 d and cooked to 75°C compared to all other treatments.

Re-purchase intention scores were influenced only by cooking and interactions with ageing period and endpoint temperature (Table 27) – cooking effects were due to cooking method (P<0.0065), between steaks and all other cuts (P<0.0001) and cut type (P<0.0001). Pork from shoulders had higher (P<0.0001) re-purchase intention scores than roast and stir fry from the loin, with no difference in average re-purchase intention scores for loin steak, silverside roast and stir fry. Average re-purchase intention scores for stir fry cuts were only 0.10 units higher (P=0.0065) than roasts and 0.49 units higher than loin steaks. When aged for 7 d, re-purchase intention scores for stir fry cuts increased by 0.27 units compared with 2d aged product whilst no differences were observed for roasts aged for 2 or 7d. The interaction between ageing period, temperature and cut type was also significant for re-purchase intention and again due to the high scores for shoulder stir fry aged for 7 d and cooked to 75°C compared to all other treatments.

Table 21: Effect of gender (S), ageing period (A), endpoint temperature (T) and cooking (C) and their interactions on consumer scores for aroma

Gender	Ageing period	Temp	Cooking treatment								s.e.d.	P value*
			Blade	Chuck tender	Loin			Silverside				
			Roast	Stir fry	Roast	Stir fry	Steak	Roast	Stir fry	Average		
Entire male	2	70	59.59	67.88	60.64	60.17	60.74	57.79	61.61	*61.20*	1.133	C (P<0.0001)
	7	70	54.75	65.14	56.74	64.36	60.10	53.33	62.72	*59.59*		C_R (P<0.0001)
	2	75	59.93	69.57	57.38	64.95	67.68	59.20	68.12	*63.83*		TC_R (P=0.037)
	7	75	57.66	76.70	62.09	68.64	64.95	60.54	67.16	*65.39*		AC_R (P=0.0221)
Immunocastrate	2	70	61.93	65.87	61.19	72.34	64.33	57.33	70.40	*64.77*		
	7	70	56.35	62.39	56.56	75.80	62.94	52.12	70.78	*62.42*		
	2	75	54.47	59.78	50.14	69.33	63.48	50.95	69.13	*59.61*		
	7	75	53.22	67.91	55.86	74.03	61.76	53.29	69.17	*62.18*		
Average			*57.24*	*66.90*	*57.57*	*68.70*	*63.25*	*55.57*	*67.39*			

* Where: C compares the seven cuts evaluated

C_R allows for comparison between roast and stir fry cuts

TC_Stk – allows for comparison between Loin Steak and all other cut x cooking method treatments and endpoint temperature

AC_R – allows for comparison between roast and stir fry cuts and ageing period

Table 22: Effect of gender (S), ageing period (A), endpoint temperature (T) and cooking (C) and their interactions on consumer scores for tenderness

Gender	Ageing period	Temp	Cooking treatment								s.e.d.	P value*
			Blade	Chuck tender	Loin			Silverside				
			Roast	Stir fry	Roast	Stir fry	Steak	Roast	Stir fry	*Average*		
Entire male	2	70	71.24	71.53	56.46	54.68	47.22	50.84	41.99	*56.28*	1.984	C (P<0.0001)
	7	70	68.73	76.90	57.61	63.24	55.28	48.83	45.93	*59.50*		C_Stk (P<0.0001)
	2	75	74.84	73.77	61.85	59.43	50.82	54.43	48.28	*60.49*		C_Cut (P<0.0001)
	7	75	74.15	85.09	56.42	55.11	50.68	53.40	45.72	*60.08*		C_RxCut (P=0.0009)
Immunocastrate	2	70	73.28	75.64	62.18	57.17	49.46	53.42	49.50	*60.09*		AC (P=0.097)
	7	70	70.35	80.58	62.91	65.31	57.09	50.99	53.00	*62.89*		AC_R (P=0.011)
	2	75	68.28	69.27	58.97	53.32	44.45	48.41	47.18	*55.70*		ATC_Cut (P=0.034)
	7	75	72.54	85.56	58.50	53.96	49.28	52.34	49.58	*60.25*		
Average			*71.68*	*77.29*	*59.36*	*57.78*	*50.54*	*51.58*	*47.65*			

* Where: C compares the seven cuts evaluated
C_Stk allows for comparison between Loin Steak and average score of all other cut x cooking method treatments
C_Cut allows for comparisons between cuts (loin, silverside and shoulder)
C_RxCut allows for comparison between cut (loin, silverside and shoulder) x cooking method (roast or stir fry)
AC allows for comparison between all seven cuts evaluated with ageing period
AC_R – allows for comparison between roast and stir fry cuts and ageing period
ATC_Cut – allows for comparison between ageing period, endpoint temperature and cuts (loin, silverside and shoulder)

Table 23: Effect of gender (S), ageing period (A), endpoint temperature (T) and cooking (C) and their interactions on consumer scores for juiciness

Gender	Ageing period	Temp	Cooking treatment								s.e.d.	P value*
			Blade	Chuck tender	Loin			Silverside				
			Roast	Stir fry	Roast	Stir fry	Steak	Roast	Stir fry	*Average*		
Entire male	2	70	67.66	74.45	56.51	58.05	53.07	53.42	52.66	*59.40*	1.477	T (P=0.092)
	7	70	65.91	75.71	56.10	64.08	58.98	50.89	54.74	*60.91*		C (P<0.0001)
	2	75	69.56	75.93	58.02	55.95	48.86	54.48	55.94	*59.82*		C_Stk (P<0.0001)
	7	75	66.67	80.14	56.92	51.15	50.47	50.95	47.95	*57.75*		C_R (P=0.0025)
Immunocastrate	2	70	70.55	77.34	59.40	60.94	55.96	56.31	55.55	*62.29*		C_Cut (P<0.0001)
	7	70	69.19	78.98	59.37	67.35	62.25	54.16	58.01	*64.19*		C_RxCut (P=0.0009)
	2	75	64.88	71.25	53.34	51.26	44.18	49.80	51.26	*55.14*		TC (P=0.032)
	7	75	69.65	83.12	59.90	54.13	53.45	53.93	50.93	*60.73*		TC_Stk (P=0.043)
Average			*68.01*	*77.12*	*57.44*	*57.86*	*53.40*	*52.99*	*53.38*			

* Where: T compares the endpoint temperatures evaluated
C compares the seven cuts evaluated
C_Stk allows for comparison between Loin Steak and average score of all other cut x cooking method treatments
C_R allows for comparison between roast and stir fry cuts
C_Cut allows for comparison between cut (loin, silverside and shoulder)
C_RxCut allows for comparison between cut (loin, silverside and shoulder) x cooking method (roast or stir fry)
TC allows for comparison between all seven cuts evaluated with endpoint temperature
TC_Stk – allows for comparison between Loin Steak and all other cut x cooking method treatments and endpoint temperature

Table 24: Effect of gender (S), ageing period (A), endpoint temperature (T) and cooking (C) on consumer scores for flavour

Gender	Ageing period	Temp	Cooking treatment								s.e.d.	P value*
			Blade	Chuck tender	Loin			Silverside				
			Roast	Stir fry	Roast	Stir fry	Steak	Roast	Stir fry	*Average*		
Entire male	2	70	67.45	69.90	64.07	60.13	57.47	58.98	55.06	61.87	1.551	C (P<0.0001)
	7	70	61.57	67.99	60.31	65.20	57.72	53.51	56.06	60.34		C_Stk (P<0.0001)
	2	75	70.94	73.45	62.06	60.53	57.98	60.85	59.26	63.58		C_R (P=0.0001)
	7	75	67.57	80.22	64.37	60.57	57.64	58.26	57.68	63.76		C_Cut (P<0.0001)
Immunocastrate	2	70	70.31	72.13	60.20	61.92	57.08	55.93	60.45	62.57		TC (P=0.0526)
	7	70	69.29	75.09	61.29	71.86	62.19	55.32	66.32	65.91		TC_Cut (P=0.027)
	2	75	66.51	68.38	50.90	55.04	50.30	50.51	57.37	57.00		AC_R (P=0.0051)
	7	75	68.62	80.64	58.68	60.55	55.44	53.40	61.27	62.66		
Average			*67.78*	*73.48*	*60.24*	*61.98*	*56.98*	*55.84*	*59.18*			

* Where: C compares the seven cuts evaluated
C_Stk allows for comparison between Loin Steak and average score of all other cut x cooking method treatments
C_R allows for comparison between roast and stir fry cuts
C_Cut allows for comparison between cut (loin, silverside and shoulder)
TC allows for comparison between all seven cuts evaluated with endpoint temperature
TC_Cut – allows for comparison between cut (loin, silverside and shoulder) and endpoint temperature
AC_R – allows for comparison between roast and stir fry cuts and ageing period

Table 25: Effect of gender (S), ageing period (A), endpoint temperature (T) and cooking (C) on consumer scores for overall liking

Gender	Ageing period	Temp	Cooking treatment								s.e.d.	P value*
			Blade	Chuck tender	Loin			Silverside				
			Roast	Stir fry	Roast	Stir fry	Steak	Roast	Stir fry	Average		
Entire male	2	70	70.70	71.08	61.96	59.93	57.10	56.47	52.18	61.34	1.655	A (P=0.034)
	7	70	65.92	71.00	61.50	66.52	58.26	52.77	55.17	61.59		C (P<0.0001)
	2	75	71.82	71.81	61.05	57.77	51.74	57.41	51.89	60.50		C_Stk (P<0.0001)
	7	75	71.51	82.54	62.17	57.46	55.40	56.64	53.27	62.71		C_R (P=0.0006)
Immunocastrate	2	70	70.88	76.62	58.67	63.47	57.08	54.52	58.11	62.77		C_Cut (P<0.0001)
	7	70	69.24	79.68	61.33	73.19	61.37	53.94	64.23	66.14		C_RxCut (P=0.047)
	2	75	66.57	71.91	52.32	55.88	46.28	50.01	52.38	56.48		TC (P=0.0072)
	7	75	69.90	86.30	57.08	59.21	53.59	52.89	57.41	62.34		TC_Cut (P=0.007)
Average		70	*69.57*	*76.37*	*59.51*	*61.68*	*55.10*	*54.33*	*55.58*	*61.73*		AC_R (P=0.0049)

* Where: C compares the seven cuts evaluated

C_Stk allows for comparison between Loin Steak and average score of all other cut x cooking method treatments

C_R allows for comparison between roast and stir fry cuts

C_RxCut allows for comparison between cut (loin, silverside and shoulder) x cooking method (roast or stir fry)

TC allows for comparison between all seven cuts evaluated with endpoint temperature

TC_Stk – allows for comparison between Loin Steak and all other cut x cooking method treatments and endpoint temperature

TC_R – allows for comparison between roast and stir fry cuts and endpoint temperature

Table 26: Effect of gender (S), ageing period (A), endpoint temperature (T) and cooking (C) on consumer scores for quality grade score

Gender	Ageing period	Temp	Cooking treatment								s.e.d.	P value
			Blade	Chuck tender	Loin			Silverside				
			Roast	Stir fry	Roast	Stir fry	Steak	Roast	Stir fry	Average		
Entire male	2	70	3.75	3.89	3.36	3.27	3.29	3.19	3.01	*3.39*	0.077	C (P<0.0001)
	7	70	3.70	3.85	3.36	3.73	3.45	3.09	3.11	*3.47*		C_Stk (P<0.0001)
	2	75	3.80	3.75	3.31	3.19	3.16	3.21	3.00	*3.35*		C_R (P=0.0014)
	7	75	3.63	4.35	3.33	3.18	3.30	3.13	2.93	*3.41*		C_Cut (P<0.0001)
Immunocastrate	2	70	3.89	4.17	3.41	3.45	3.11	3.11	3.31	*3.49*		C_RxCut (P=0.0253)
	7	70	3.79	4.09	3.37	3.87	3.23	2.97	3.37	*3.53*		TC (P=0.063)
	2	75	3.78	3.87	3.21	3.22	2.82	2.98	3.14	*3.29*		TC_Cut (P=0.053)
	7	75	3.76	4.63	3.38	3.36	3.12	3.05	3.23	*3.50*		AC_R (P=0.0045)
Average			*3.76*	*4.08*	*3.34*	*3.41*	*3.18*	*3.09*	*3.14*			ATC _RxCut (P=0.0062)

* Where: C compares the seven cuts evaluated

C_Stk allows for comparison between Loin Steak and average score of all other cut x cooking method treatments
C_R allows for comparison between roast and stir fry cuts
C_RxCut allows for comparison between cut (loin, silverside and shoulder) x cooking method (roast or stir fry)
TC allows for comparison between all seven cuts evaluated with endpoint temperature
TC_Stk – allows for comparison between Loin Steak and all other cut x cooking method treatments and endpoint temperature
TC_R – allows for comparison between roast and stir fry cuts and endpoint temperature
AC_R – allows for comparison between roast and stir fry cuts and ageing period
ATC_RxCut – allows for comparison between ageing period, endpoint temperature, cut type (loin, silverside and shoulder) and roasts and stir fry cuts

Table 27: Effect of gender, ageing period, endpoint temperature, cut type and cooking method on consumer scores for re-purchase intention

Gender	Ageing period	Temp	Cooking treatment								s.e.d.	P value
			Blade	Chuck tender	Loin			Silverside				
			Roast	Stir fry	Roast	Stir fry	Steak	Roast	Stir fry	Average		
Entire male	2	70	3.73	3.83	3.33	3.31	3.24	3.22	2.84	*3.36*	0.094	C (P<0.0001)
	7	70	3.85	3.93	3.36	3.85	3.45	3.21	3.01	*3.52*		C_Stk (P<0.0001)
	2	75	4.05	3.82	3.43	3.26	3.20	3.44	2.98	*3.45*		C_R (P=0.0065)
	7	75	3.72	4.38	3.34	3.20	3.16	3.17	2.77	*3.39*		C_Cut (P<0.0001)
Immunocastrate	2	70	3.90	4.25	3.36	3.57	2.99	2.96	3.35	*3.48*		TC (P=0.066)
	7	70	4.02	4.35	3.40	4.10	3.20	2.95	3.52	*3.65*		TC_Cut (P=0.067)
	2	75	3.94	3.96	3.18	3.23	2.67	2.90	3.21	*3.30*		AC_R (P=0.0074)
	7	75	3.92	4.82	3.40	3.48	2.94	2.94	3.31	*3.54*		ATC _RxCut (P=0.0144)
Average			*3.89*	*4.17*	*3.35*	*3.50*	*3.11*	*3.10*	*3.12*			

* Where: C compares the seven cuts evaluated
C_Stk allows for comparison between Loin Steak and average score of all other cut x cooking method treatments
C_R allows for comparison between roast and stir fry cuts
C_Cut allows for comparison between cuts (loin, silverside and shoulder)
TC allows for comparison between all seven cuts evaluated with endpoint temperature
TC_Cut – allows for comparison between Loin Steak and all other cut x cooking method treatments and endpoint temperature
AC_R allows for comparison between roast and stir fry cuts and ageing period
ATC_RxCut – allows for comparison between ageing period, endpoint temperature, cut type (loin, silverside and shoulder) and roasts and stir fry cuts

The percentage of pork samples that obtained scores of less than 3 for quality grade (fail rate) and re-purchase intention scores of less than 3 (fail rate) from entire and immunocastrated males is shown in Table 28. Overall, the fail rate of pork from entire males was 2.1% higher (P>0.05) than for pork from immunocastrates. The percentage of evaluations of pork from entire males that were rated as either 1 or 2 (I definitely would not buy it' or 'I would probably not buy it') for re-purchase intention was 3.9% higher (P>0.05)than for pork from immunocastrates.

Table 28: Percentage of consumer scores for quality grade and re-purchase intention for pork from entire males and immunocastrates across all treatments (n=1120 evaluations per row)

	Quality grade score					Fail rate	P value
	1	2	3	4	5	(% <3)	
Entire males	2.32	15.45	37.32	29.29	15.63	17.8	P>0.05
Immunocastrates	1.96	13.75	37.05	31.52	15.71	15.7	
	Re-purchase intention score					Would not	
	1	2	3	4	5	purchase(%<3)	
Entire males	6.34	17.77	26.25	26.43	23.21	24.1	P>0.05
Immunocastrates	6.70	16.70	23.48	26.79	26.34	20.2	

The fail rates for each cut x cooking method combination taking into account gender of the pig, ageing period and endpoint temperature are presented for quality grade scores in Table 24 and re-purchase intention in Table 25.

Table 29: Percentage of consumer scores for quality grade for pork from different cuts and cooking method, gender (entire male, immunocastrate), ageing period (2 or 7d) and endpoint temperature (70 or 75° C) (n=40 evaluations per column within cut)

	Grade score	Entire male				Immunocastrate				Fail rate	P value
		2d		7d		2d		7d			
		70°C	75°C	70°C	75°C	70°C	75°C	70°C	75°C	(%<3)	
Shoulder (Blade) Roast											P<0.05
	1	0	0	2.5	0	0	0	0	2.5		
	2	7.5	5	10	2.5	2.5	2.5	7.5	2.5		
	3	30	32.5	32.5	47.5	37.5	22.5	20	35		
	4	47.5	40	32.5	35	32.5	62.5	52.5	32.5		
	5	15	22.5	22.5	15	27.5	12.5	20	27.5		
Fail rate (%<3)		*7.5*	*5.0*	*12.5*	*2.5*	*2.5*	*2.5*	*7.5*	*5.0*	*5.6*	
Shoulder (Chuck tender) Stir fry											
	1	0	0	0	0	0	0	0	0		
	2	7.5	5	5	5	5	10	5	0		
	3	30	30	17.5	5	10	25	32.5	5		
	4	40	35	35	27.5	47.5	37.5	40	40		
	5	22.5	30	42.5	62.5	37.5	27.5	22.5	55		
Fail rate (%<3)		*7.5*	*5*	*5*	*5*	*5*	*10*	*5*	*0*	*5.3*	
Loin Roast											
	1	0	2.5	2.5	0	2.5	0	0	5		
	2	20	20	17.5	10	17.5	15	17.5	22.5		
	3	40	45	42.5	40	35	42.5	40	25		
	4	32.5	20	17.5	35	32.5	32.5	25	42.5		
	5	7.5	12.5	20	15	12.5	10	17.5	5		
Fail rate (%<3)		*20*	*22.5*	*20*	*10*	*20*	*15*	*17.5*	*27.5*	*19.1*	

	Grade score	Entire male				Immunocastrate				Fail rate (%<3)	P value
		2d		7d		2d		7d			
		70°C	75°C	70°C	75°C	70°C	75°C	70°C	75°C		
Loin Stir Fry											
	1	0	2.5	0	0	2.5	0	0	2.5		
	2	17.5	15	2.5	25	10	15	2.5	12.5		
	3	40	52.5	50	35	45	50	27.5	47.5		
	4	32.5	22.5	25	27.5	32.5	30	55	22.5		
	5	10	7.5	22.5	12.5	10	5	15	15		
Fail rate (%<3)		*17.5*	*17.5*	*2.5*	*25*	*12.5*	*15*	*2.5*	*15*	*13.4*	
Loin Steak											
	1	2.5	5	2.5	5	5	2.5	0	5		
	2	12.5	20	22.5	20	25	32.5	15	25		
	3	42.5	37.5	50	30	35	47.5	50	42.5		
	4	27.5	25	15	27.5	17.5	7.5	22.5	12.5		
	5	15	12.5	10	17.5	17.5	10	12.5	15		
Fail rate (%<3)		*15*	*25*	*25*	*25*	*30*	*35*	*15*	*30*	*25*	
Silverside Roast											
	1	2.5	5	12.5	5	2.5	2.5	5	7.5		
	2	17.5	27.5	22.5	25	27.5	17.5	20	15		
	3	40	35	40	40	40	32.5	47.5	42.5		
	4	30	30	17.5	25	22.5	40	17.5	22.5		
	5	10	2.5	7.5	5	7.5	7.5	10	12.5		
Fail rate (%<3)		*20*	*32.5*	*35*	*30*	*30*	*20*	*25*	*22.5*	*26.9*	
Silverside Stir Fry											
	1	2.5	7.5	5	0	0	2.5	2.5	5		
	2	30	20	20	20	10	12.5	17.5	20		
	3	40	40	32.5	47.5	57.5	60	37.5	45		
	4	22.5	22.5	40	32.5	27.5	20	32.5	22.5		
	5	5	10	2.5	0	5	5	10	7.5		
Fail rate (%<3)		*32.5*	*27.5*	*25*	*20*	*10*	*15*	*20*	*25*	*21.9*	

Table 30: Percentage of consumer scores for re-purchase intention for pork from different cuts and cooking method, genders (entire males, immunocastrate), ageing period (2 or 7d) and endpoint temperature (70 or 75C) (n=40 evaluations per column within cut)

	Grade score	Entire male				Immunocastrate				Fail rate	P value
		2d		7d		2d		7d			
		70°C	75°C	70°C	75°C	70°C	75°C	70°C	75°C	(%<3)	
Shoulder (Blade) Roast											P<0.05
	1	0	0	5	2.5	0	0	2.5	2.5		
	2	17.5	5	10	5	10	5	5	7.5		
	3	20	32.5	25	40	25	12.5	17.5	15		
	4	37.5	40	25	25	25	60	40	35		
	5	25	22.5	35	27.5	40	22.5	35	40		
Fail rate (%<3)		*17.5*	*5*	*15*	*7.5*	*10*	*5*	*7.5*	*10*	*9.7*	
Shoulder (Chuck tender) Stir fry											
	1	0	2.5	0	2.5	0	0	2.5	0		
	2	20	5	7.5	2.5	5	12.5	10	0		
	3	15	17.5	10	0	12.5	20	22.5	10		
	4	35	35	30	30	30	32.5	22.5	20		
	5	30	40	52.5	65	52.5	35	42.5	70		
Fail rate (%<3)		*20*	*7.5*	*7.5*	*5*	*5*	*12.5*	*12.5*	*0*	*8.8*	
Loin Roast											
	1	5	5	10	0	10	2.5	10	10		
	2	22.5	25	17.5	17.5	15	22.5	22.5	27.5		
	3	27.5	32.5	27.5	27.5	27.5	30	17.5	10		
	4	27.5	15	20	30	25	25	20	37.5		
	5	17.5	22.5	25	25	22.5	20	30	15		
Fail rate (%<3)		*27.5*	*30*	*27.5*	*17.5*	*25*	*25*	*32.5*	*37.5*	*27.8*	
Loin Stir Fry											
	1	0	5	0	7.5	5	2.5	0	7.5		
	2	20	20	7.5	20	15	27.5	10	15		
	3	35	35	40	25	25	25	10	30		
	4	27.5	25	20	20	37.5	35	45	25		
	5	17.5	15	32.5	27.5	17.5	10	35	22.5		
Fail rate (%<3)		*20*	*25*	*7.5*	*27.5*	*20*	*30*	*10*	*22.5*	*20.3*	
Loin Steak											
	1	7.5	10	2.5	17.5	10	20	2.5	12.5		
	2	12.5	25	35	17.5	32.5	22.5	17.5	35		
	3	37.5	22.5	30	17.5	22.5	32.5	35	22.5		
	4	25	22.5	22.5	22.5	12.5	10	30	7.5		
	5	17.5	20	10	25	22.5	15	15	22.5		
Fail rate (%<3)		*20*	*35*	*37.5*	*35*	*42.5*	*42.5*	*20*	*47.5*	*35*	
Silverside Roast											
	1	5	10	12.5	25	20	12.5	10	10		
	2	20	30	35	10	20	7.5	20	32.5		
	3	30	20	25	22.5	22.5	22.5	30	22.5		
	4	30	22.5	15	30	20	35	20	12.5		
	5	15	17.5	12.5	12.5	17.5	22.5	20	22.5		
Fail rate (%<3)		*25*	*40*	*47.5*	*35*	*40*	*20*	*30*	*42.5*	*35*	
Silverside Stir Fry											
	1	12.5	10	10	10	2.5	10	12.5	10		
	2	22.5	20	27.5	20	17.5	17.5	12.5	22.5		
	3	37.5	30	20	32.5	35	42.5	25	35		
	4	22.5	25	32.5	27.5	30	17.5	27.5	12.5		
	5	5	15	10	10	15	12.5	22.5	20		
Fail rate (%<3)		*35*	*30*	*37.5*	*30*	*20*	*27.5*	*25*	*32.5*	*29.7*	

Further analyses were conducted to determine whether the lack of difference in eating quality identified in this study between entire males and immunocastrated males may be explained by demographic effects due to consumers involved in this study.

Overall, male consumers scored overall liking of pork about 2.5 units lower than female consumers (60.64±14.48 vs. 63.25±12.95, respectively) across all treatments. The average overall liking scores across male and female consumers in each of the six age groups are shown in Table 31. For the two youngest age groups, males scored pork lower for overall liking than females, but for the last four age groups, males scored higher than females

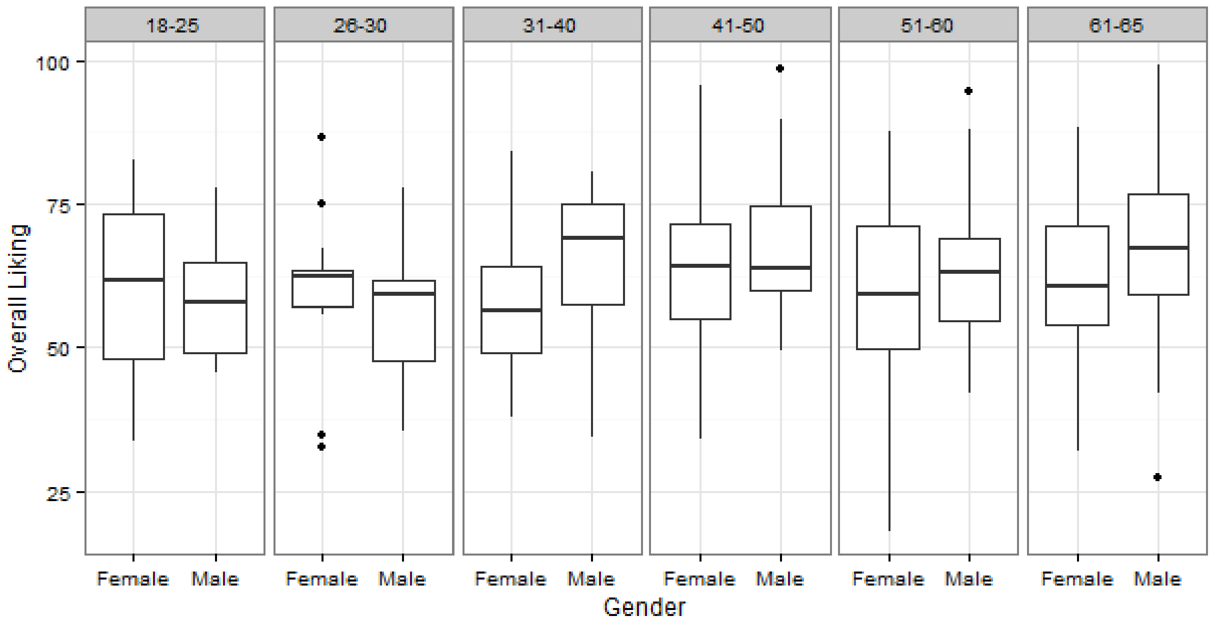


Figure 1: Effect of consumer age on overall liking scores for pork provided by female and male consumers

In the sensory design used in this study, each consumer tasted seven samples and these seven samples may have been from either 7 or 28 day ageing treatments. In total, 40 consumers had pork samples that were aged for the same period of time (either 7 or 28 days) whilst 280 samples consumed pork from both ageing periods (3 from one ageing period and 4 samples from the other). Consumers who only tasted pork from one ageing period had a lower overall liking scores compared with those who evaluated pork from both ageing periods (60.56±13.24 vs. 61.90±14.00, respectively).

Linear regression analyses indicated that no differences between male and female consumers (P=0.097), age group of consumers (P=0.071), pig gender (P=0.64), endpoint temperature (P=0.50) or ageing period (P=0.70) were found for overall liking scores.

The skatole and androstenone levels in each of the forty pigs involved in this study were matched with the individual scores given for each cut by each consumer, according to endpoint temperature (Figure 2) and ageing period (Figure 3). Three classifications for entire males were made – normal, high androstenone (androstenone levels >1μg/g). boar taint (androstenone levels >1μg/g and skatole levels > 0.2μg/g) .

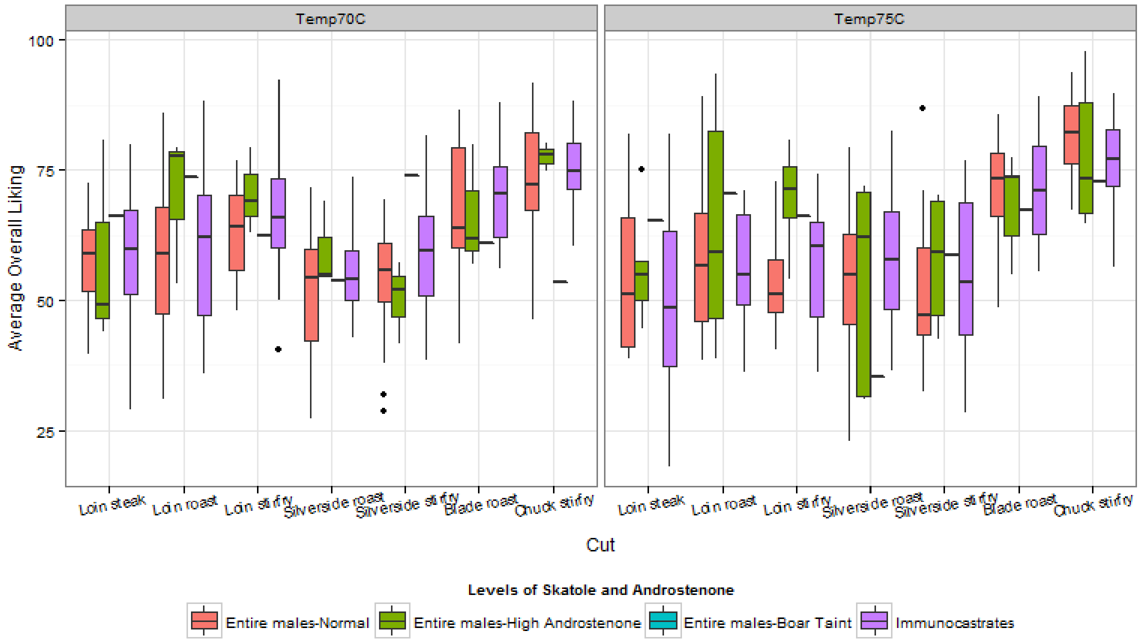


Figure 2: Average overall liking scores for pork from different cut x cooking method treatments sourced from entire male and immunocastrated males and cooked to 70 or 75°C.

No consistent effect on average overall liking scores from pork due to high levels of androstenone (n=3) and with boar taint (n=2) for the different pork cuts cooked to an endpoint temperature of 70°C or 75°C (Figure 2). Similar results were found when average liking scores of the seven different pork cuts aged for 2 or 7 days from entire male pigs with low levels of androstenone and skatole (normal), high androstenone and boar taint compared with immunocastrates (Figure 3).

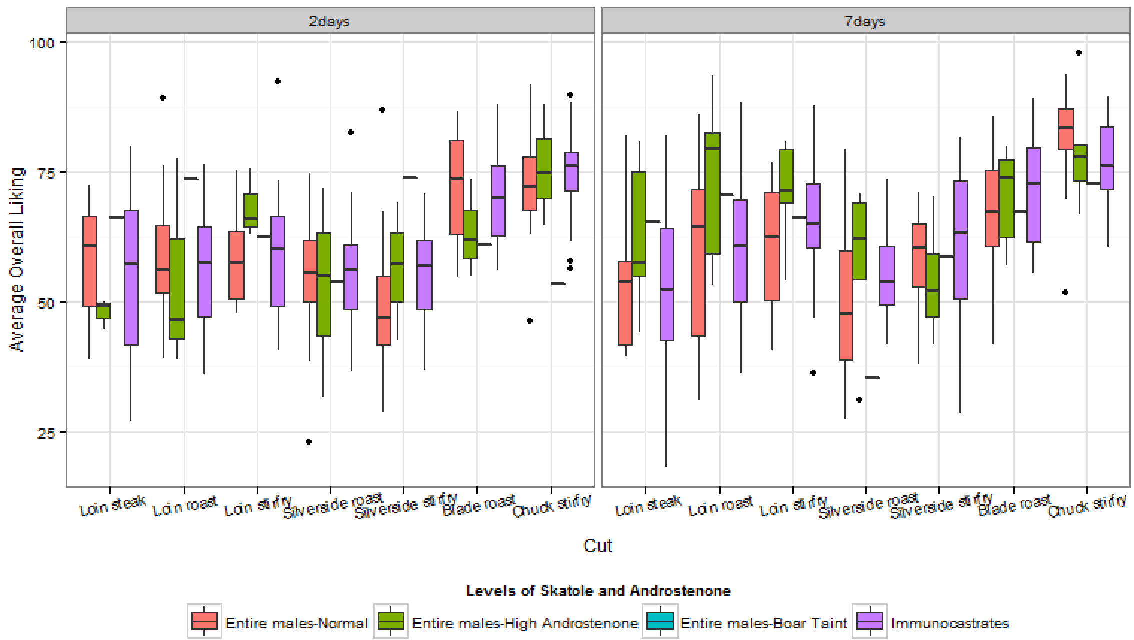


Figure 3: Average overall liking scores for pork from different cut x cooking method treatments sourced from entire male and immunocastrated males and aged for 2 or 7 d

Average overall liking scores of pork (across all cuts and cooking methods) from pigs with higher levels of androstenone and with boar taint were not lower than those from pigs with lower levels of androstenone and skatole (Figure 4).

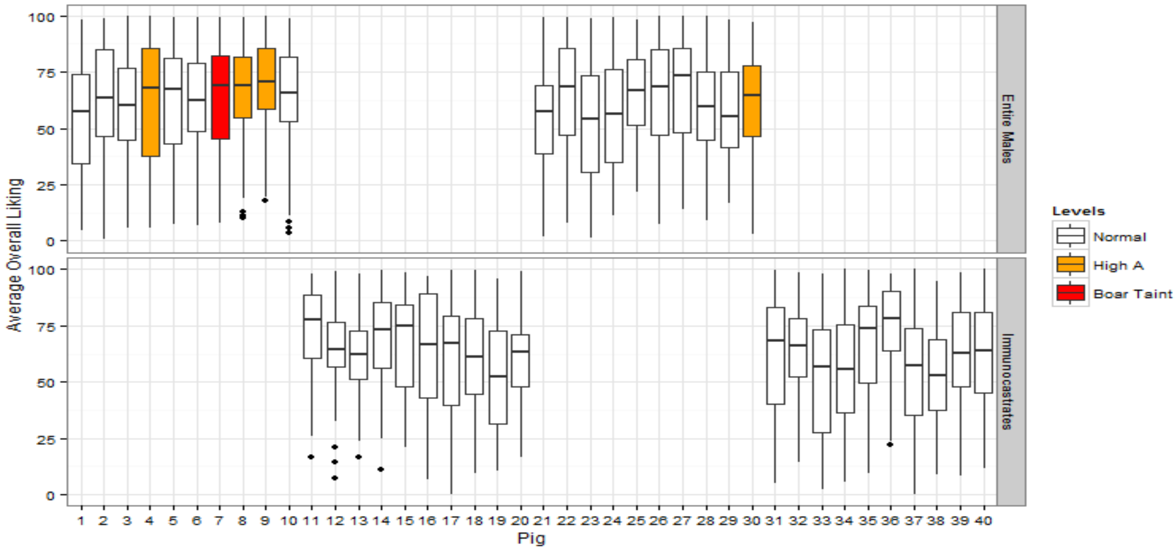


Figure 4: Average overall liking scores for pork sourced from entire male and immunocastrated males (NB: Pig 8 also has boar taint)

No effect of gender of consumer on overall liking of pork for each pig was observed, despite differences in androstenone and skatole levels (Figure 5).

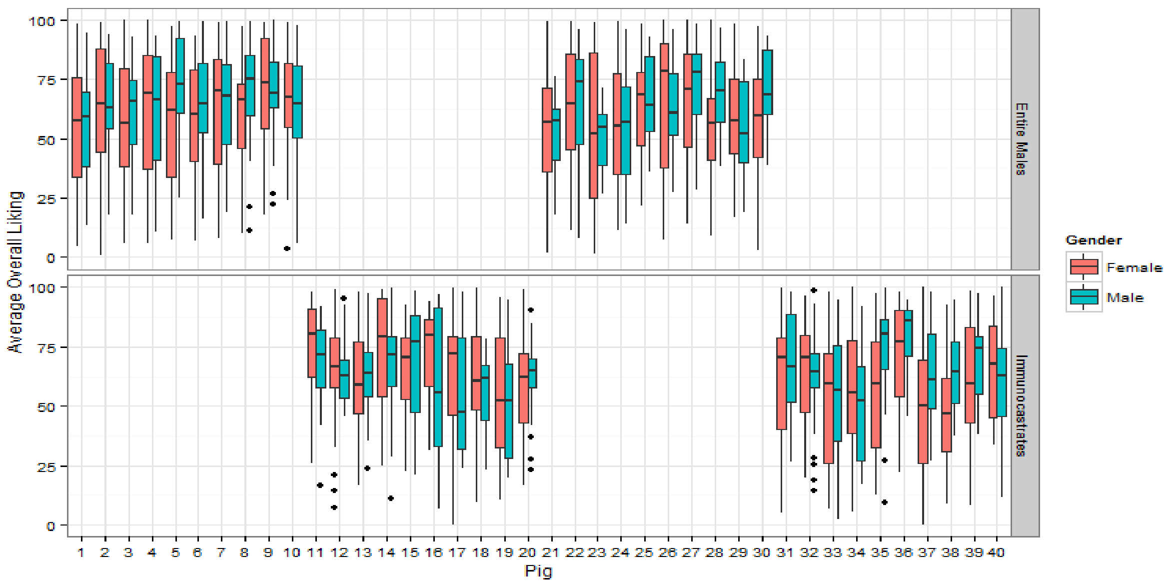
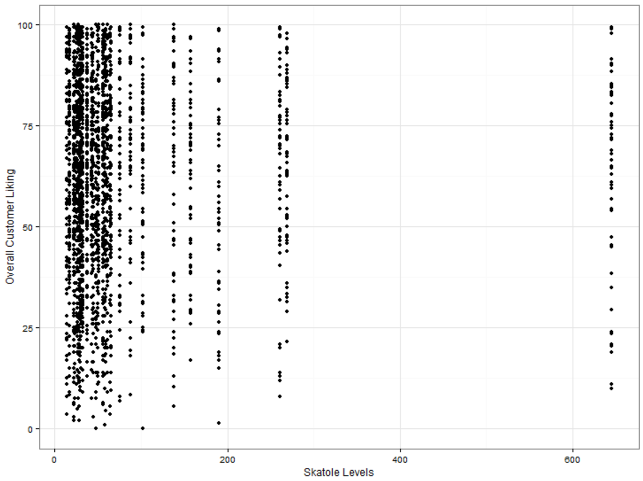


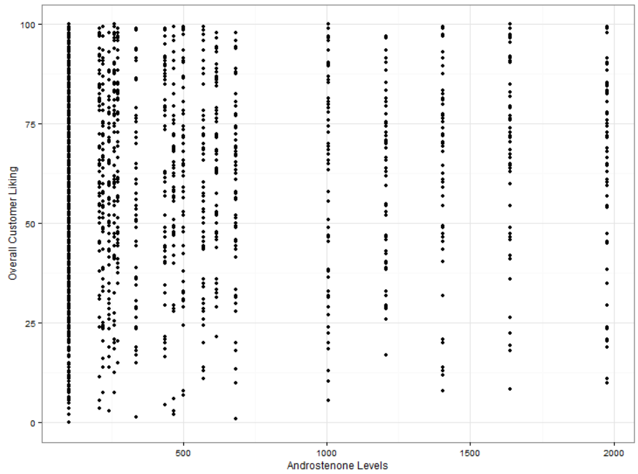
Figure 5: Average overall liking scores for pork sourced from entire male and immunocastrated males and assessed by female and male consumers

Overall, correlations between aroma, tenderness, juiciness, flavour and overall liking with objective measurements (ultimate pH, colour, drip loss, purge, WBSF, intramuscular fat, androstenone and skatole) were low for both shoulder and silverside (Table 31) and loin (Table 32). Intramuscular fat content was moderately correlated with aroma, flavour and overall liking of blade roast. WBSF was also moderately correlated with tenderness and overall liking of silverside stir fry.

Poor correlations between sensory attributes and androstenone or skatole and for all cuts evaluated in this study were found.

Figures 6 and 7 also demonstrate that the relationships between individual consumer scores for overall liking of pork and skatole and androstenone levels in pork (across all cuts and treatments) were weak.





Figures 6 and 7: Influence of skatole (left) and androstenone (right) levels on overall liking scores for pork (across all treatment combinations)

Table 31 Correlation matrix between sensory attributes of shoulder roast (*M. triceps brachii*), shoulder stir fry (*M. supraspinatus*) and silverside (*M. biceps femoris*) roast and stir fry and objective measurements of ultimate pH, L*, a* and b* values, intramuscular fat, androstenone and skatole concentrations and for silverside only drip loss, purge, WB shear force (WBSF) and cooking loss (correlations in bold are significant P<0.05, n=80)

	Roast					Stir Fry				
	Aroma	Tenderness	Juiciness	Flavour	Overall liking	Aroma	Tenderness	Juiciness	Flavour	Overall liking
Shoulder										
Ultimate pH	0.035	0.161	0.083	0.092	0.163	-0.063	-0.049	-0.111	0.083	-0.140
L* value	0.117	-0.062	-0.127	-0.029	-0.058	-0.086	-0.144	-0.111	-0.015	-0.060
a* value	-0.108	-0.004	0.257	0.021	0.031	-0.026	-0.111	-0.070	-0.085	-0.119
b* value	-0.114	-0.076	0.206	-0.063	-0.077	0.025	-0.205	-0.144	-0.043	-0.152
Intramuscular fat (%)	**0.253**	0.114	0.043	**0.226**	**0.287**	ND	ND	ND	ND	ND
Androstenone	-0.134	-0.110	-0.142	-0.088	-0.132	0.023	-0.043	0.079	0.028	-0.036
Skatole	-0.121	-0.183	-0.198	-0.083	-0.168	0.060	-0.178	0.018	-0.137	-0.194
Silverside										
Ultimate pH	0.085	-0.077	0.015	-0.106	-0.051	-0.035	-0.002	-0.068	0.013	0.012
L* value	0.209	0.027	0.003	0.024	0.066	-0.090	0.119	0.029	0.111	0.156
a* value	-0.097	0.042	0.077	0.065	0.045	0.056	-0.142	-0.051	-0.087	-0.121
b* value	0.082	0.046	0.011	-0.004	0.022	-0.010	-0.005	-0.070	0.037	0.064
Intramuscular fat (%)	0.018	-0.019	0.060	0.077	0.094	0.083	0.065	0.021	0.058	0.081
Drip loss (%)	**-0.249**	-0.024	-0.067	-0.118	-0.108	-0.094	-0.087	0.029	-0.103	-0.113
Purge (%)	-0.061	-0.156	-0.084	-0.060	-0.106	-0.087	-0.078	0.004	-0.038	-0.095
WBSF (N)	-0.007	-0.117	-0.057	-0.051	-0.089	-0.061	**-0.302**	-0.158	-0.150	**-0.239**
Cooking loss (%)	-0.033	0.051	0.016	-0.040	0.008	-0.152	-0.097	-0.109	-0.077	-0.167
Androstenone	-0.020	-0.084	-0.182	-0.040	-0.054	0.003	-0.038	-0.102	0.018	0.019
Skatole	-0.086	-0.055	-0.124	-0.053	-0.029	0.018	-0.009	-0.066	0.027	0.077

For the loin, negative correlations between WBSF and sensory tenderness, flavour and overall liking were significant for roast and stir fry (Table 32). For steaks, only sensory tenderness and overall liking were moderately negatively correlated with WBSF. Significant, negative, correlations between cooking loss and juiciness for both loin steaks and stir fry and cooking loss and overall liking for stir fry were also found.

Table 32 Correlation matrix between sensory attributes of loin (*M. longissimus dorsi*), roast, stir fry and steak and objective measurements of ultimate pH, L*, a* and b* values, intramuscular fat, drip loss, purge, WB shear force (WBSF), cooking loss and androstenone and skatole concentrations (correlations in bold are significant P<0.05, n=80)

	Aroma	Tendernes s	Juiciness	Flavour	Overall liking
Roast					
Ultimate pH	0.100	0.122	0.090	0.107	0.115
L* value	0.071	**0.249**	0.201	**0.293**	**0.296**
a* value	0.201	-0.118	-0.074	-0.046	-0.082
b* value	0.161	0.098	0.087	0.204	0.210
Intramuscular fat (%)	0.051	0.010	0.006	0.019	-0.011
Drip loss (%)	-0.155	-0.206	-0.219	-0.211	-0.208
Purge (%)	0.174	0.051	0.094	0.069	0.037
WBSF (N)	-0.132	**-0.220**	-0.172	**-0.223**	**-0.255**
Cooking loss (%)	-0.090	-0.036	-0.048	-0.062	-0.071
Androstenone	0.038	0.121	0.175	0.222	0.215
Skatole	-0.034	0.082	0.112	0.107	0.131
Steak					
Ultimate pH	0.042	-0.122	-0.116	-0.074	-0.116
L* value	-0.032	0.121	**0.247**	0.076	0.185
a* value	-0.105	-0.158	-0.169	-0.103	-0.095
b* value	-0.116	-0.091	-0.065	-0.084	0.016
Intramuscular fat (%)	-0.063	**-0.228**	-0.173	-0.216	-0.209
Drip loss (%)	-0.024	0.025	0.042	0.079	0.072
Purge (%)	0.004	-0.089	-0.004	0.006	-0.013
WBSF (N)	0.075	**-0.238**	-0.171	-0.214	**-0.295**
Cooking loss (%)	0.146	-0.110	**-0.236**	-0.129	-0.196
Androstenone	-0.080	0.120	-0.027	0.035	0.079
Skatole	-0.023	0.116	0.061	0.061	0.096
Stir fry					
Ultimate pH	-0.036	-0.012	-0.012	-0.028	-0.098
L* value	0.114	**0.254**	0.214	0.205	**0.300**
a* value	-0.025	-0.032	0.017	-0.070	-0.044
b* value	- 0.008-	0.140	0.124	0.066	0.197
Intramuscular fat (%)	0.021	-0.079	0.020	-0.186	-0.034
Drip loss (%)	-0.125	-0.060	-0.055	-0.118	-0.069
Purge (%)	0.050	-0.059	-0.043	-0.051	-0.089
WBSF (N)	0.028	**-0.254**	**-0.248**	-0.186	**-0.288**
Cooking loss (%)	0.085	-0.103	**-0.323**	-0.188	**-0.277**
Androstenone	0.062	0.078	-0.037	0.063	0.149
Skatole	0.046	0.051	0.014	0.069	0.116

4 Application of Research

4.1 Effect of gender, ageing period, cut type, cooking method and endpoint temperature on eating quality of pork

In this study, overall liking was influenced in order by flavour, tenderness and juiciness. Aroma was not a significant term in the prediction equation for overall liking in contrast to Channon *et al.* (2013), in a similarly designed study involving entire males, females and surgically castrated male pigs of the same genotype. Overall liking was highly correlated with flavour, followed by juiciness and tenderness.

4.1.1 Gender

Improved growth performance during the finisher phase after administration of the second vaccination of immunocastrated males compared with entire males observed in this study has been previously reported (Dunshea *et al.*, 2001; Batorek *et al.*, 2012). Although immunocastration can result in increased feed intake following the second vaccination (Batorek *et al.*, 2012), it was not measured in this study. However, both fat depth at the P2 site and intramuscular fat content of the loin, silverside and blade muscles were higher in immunocastrated males compared with entire males in this study. D'Souza *et al.* (2000) and Gispert *et al.* (2010) also found higher intramuscular fat levels in loin muscles in immunocastrated males compared with entire males. Intramuscular fat content of loins from immunocastrates were intermediate between surgical castrates and entire males (Škrlep *et al.* 2010; Gispert *et al.* 2010), but Škrlep *et al.* (2010) noted that intramuscular fat levels in loins from immunocastrates were closer to entire males than surgical castrates. Dressing percentage was reduced in immunocastrated males compared to entire males in this study - this could be due to increased abdominal fat (Škrlep *et al.* 2010) and heavier gastrointestinal tract, kidneys and liver (Pauly *et al.*, 2009; Gispert *et al.*, 2010).

No effect of gender for any of the sensory attributes assessed in this study were found, despite higher levels of intramuscular fat in silverside, loin and shoulder blade muscles from immunocastrated males compared with entire males. This is in contrast to Channon *et al.* (2013) who reported small differences in juiciness, flavour, overall liking, quality grade between entire males and surgical castrates (females were intermediate). When comparing summary data from this study, average sensory scores for all attributes assessed in this study ranged from 3.3 to 6.4 units higher than those reported by Channon et al. (2013). Furthermore, average androstenone and skatole levels in entire males in the study reported by Channon *et al.* (2013) were higher (0.753±0.585 and 0.185±0.178 μg/g, respectively) compared with this study (0.617±0.547 and 0.116±0.146 μg/g, respectively).

Whilst the genetic backgrounds, age at slaughter, carcase fat levels and hot carcase weight of entire male pigs used in both studies were similar and each study was conducted at the same time of the year (but a year apart), pigs in this study were sourced from a different farm (both indoor on slatted concrete floors) compared with pigs in the earlier study. This could, in part, explain some of the differences in androstenone and skatole levels between studies. Skatole has been shown to be more highly correlated with boar taint and overall negative taste than androstenone - greater variation in odour scores of pork from entire male and female pigs has been shown to be due to skatole (Lundström *et al.*, 1988; Matthews *et al.*, 2000), with both androstenone and skatole contributing similarly to flavour. Further, Font i Furnols *et al.*, (2008) found that when pork from entire males with androstenone levels of >0.5μg/g was excluded from the analysis, no difference in pork odour between immunocastrates, females, surgical castrates and entire males was observed. For flavour, pork with low (<0.5μg/g) androstenone levels from entire males obtained lower scores than surgical castrates and immunocastrates, but not from females. It may be suggested that, at least for this study, the lack of difference in eating quality attributes between immunocastrate and entire males may reflect the lower, and less variable, androstenone and skatole levels present in entire males. In contrast, average skatole levels of immunocastrates were similar to those previously reported for surgical castrates by Channon *et al.* (2013) of 0.039 vs. 0.038 µg/g, respectively. Channon *et al.* (2013) also reported the outcomes of supplementation of 8g/kg soy lecithin to entire males, females and immunocastrated males for five weeks prior to slaughter on pork eating quality attributes. Neither gender nor diet influenced any of the sensory attributes assessed by a consumer panel. As fat samples from entire males were not assessed for androstenone and skatole concentrations, it is not known whether this lack of effect of gender on pork eating quality may have been related to low levels of androstenone and skatole present.

The findings of this study are in contrast to other studies (eg. Font i Furnois *et al.*, 2008; Lodge *et al.*, 2008; Font i Furnois *et al.*, 2009; Pauly *et al.*, 2009; Pauly *et al.*, 2010) who have compared eating quality attributes of immunocastrated males with entire male pigs. Font i Furnols *et al.* (2008) reported no difference in odour and flavour of pork loin cooked in an oven at 180°C for 10 min from surgical castrates, immunocastrates and females, however that from entire males was less accepted in terms of both odour and flavour by consumers. Odour and flavour scores were higher in pork from entire males with androstenone levels of <0.5µg/g compared with higher levels (0.5-0.99µg/g and >0.99µg/g). Using a trained panel, flavour and odour was more intense in pork from entire males compared with pork from surgical castrates and immunocastrates (Pauly *et al.*, 2010). Font i Furnols *et al.* (2009), in a study involving entire, immunocastrated and surgically castrated males and females, reported strong negative correlations between consumer scores for odour and flavour of pork loin samples and androstenone and skatole levels assessed by trained panelists. Gispert *et al.* (2010) conducted principal component analysis of sensory data reported by Font i Furnols *et al.* (2008, 2009) and showed that the horizontal axis (related to consumer and trained panel variables) explained 44.1% of the variation and the vertical axis (relating to carcase parameters and intramuscular fat content) explained 19.4% of the variation. Gispert *et al.* (2010) showed that entire males were placed on the right hand side of the plot (associated with high androstenone and skatole odour and flavour scores from trained panellists) whilst females were placed on the left side of the plot (higher aroma and flavour scores from consumers). Aroma and flavour scores were lower for pork loins from entire males compared with females, surgical castrates and immunocastrated males. Lodge *et al.* (2008), using trained panelists to evaluate pork loin steaks from immunocastrated and entire males slaughtered at 105 kg liveweight of 20 weeks of age, showed that pork from immunocastrated males had a more intense and lower abnormal flavour intensity and was also more preferred in relation to flavour and overall liking than from entire males. However, Jeong *et al.* (2008a) found no difference in sensory quality of bellies obtained from entire male, female, surgically castrated and immunocastrated males. In a meta-analysis, Pauly *et al.* (2012) also reported no differences in tenderness or juiciness between immunocastrate, surgical castrate, female or entire males. Jeong *et al.* (2008b) and Silveira *et al.* (2008), in studies conducted in South Korea and Brazil comparing sensory quality of pork loins from immunocastrate and surgically castrated pigs, found that sensory quality was comparable between these two genders.

Consumer differences between studies may have accounted for differences in amplitude in the sensory results between these two studies, as the perception of boar taint by consumers can intrinsically differ due to their origin, gender and androstenone sensitivity (Font i Furnols, 2012). Both studies were conducted by SARDI in the same sensory facilities in Adelaide using the same preparation, cooking and presentation methodologies as used in Channon *et al.* (2013). This included pork from the two different genders being cooked separately in a ventilated kitchen located away from the consumer tasting facilities so importantly, consumers were not exposed to any volatiles, fat and/or cooking odours emanating from the kitchen. Previous studies have shown that boar taint is more likely to be perceived from odours emitted during cooking.

Although no direct measurements of gender on aggressive and/or sexual behaviour, leg injuries, carcase scratches or bruising were made in this study, it was observed that immunocastrated males were quieter on-farm as well as in lairage at the abattoir compared with entire males. A reduction in aggressive and secual behavior resulting from administration of the immunocastration vaccine at 11 and 15 weeks has previously been reported (eg. Brewster and Nevel, 2013). The positive animal welfare benefits support industry's continuing advocacy to encourage the use of the immunocastration vaccine, particularly with increasing consumer awareness of how animals are being raised.

Although differences in pH and colour of pork due to gender were observed in this study, these differences were generally small. Although muscle pH of the loin from immunocastrates measured at 24 h post-slaughter was higher than entire males, similar differences were not observed between genders at either 2 or 7 d post-slaughter. Muscle pH of the silverside was lower in immunocastrates when measured at 2 d (0.07 units lower) compared with entire males, it was 0.03 units lower when measured at 7 d. This may reflect the reduction in aggressive and physical behavior of immunocastrated males (Batorek *et al.*, 2012). The gender effect for L* value for silversides was considered to result from the 2 unit higher average L* value of silversides aged for 7 d.

4.1.2 Ageing period, cut type, cooking method and effect of endpoint temperature

Very strong effects due to both cut and cooking method were found in this study. Pork from the shoulder outperformed loins and silversides for all eating quality attributes assessed. These cut differences reflect anatomical differences resulting from their different composition, sarcomere length and connective tissue contents. Sullivan and Calkins (2011) ranked beef muscles on the basis of WBSF and trained sensory panel evaluations from data compiled from previous research. For sensory juiciness, a total of 13 beef muscles were assessed and the *loin, triceps brachii, supraspinatus* and *biceps femoris* were ranked 3rd, 4th, 5th and 8th, respectively (effects of cooking method were not documented). On the basis of WBSF, the *longissimus* and *triceps brachii* were classified as intermediate and the *biceps femoris* and *supraspinatus* were classified as tough (>4.6 kg). In this study, the ranking order differed for eating quality attributes (but may have been influenced by *supraspinatus* only being used for stir fry: *supraspinatus* (stir fry) > triceps brachii (roast) > loin > silverside.

Overall, roasts were scored lower than stir fry by consumers for all sensory attributes and these differences due to cooking method were influenced by temperature and by ageing period. The interaction between ageing period and cooking method (roast and stir fry) for aroma, tenderness, flavour, overall liking, quality grade score and re-purchase intention was significant. For each of these variables, ageing for 7 d significantly reduced sensory scores for roasts compared to ageing for 2 d, whilst for stir fry, ageing for 7 d increased sensory scores compared to 2 d ageing. This finding could be interpreted as ageing being more critical in smaller cuts that are cooked quickly, such as stir fry (and steaks) compared with roasts. This was not observed in the previous study involving entire males, surgical castrates and females (Channon *et al.* 2013). In addition, Channon *et al.* (submitted) showed that ageing of both loin steaks and topside roasts for 7 d, rather than 2 d, significantly improved eating quality. The difference in average overall liking scores was also greater for topsides, cooked as roasts and presented as slices, than loin steaks following ageing for 7 d.

These findings, together with those from Channon *et al.* (2013), also suggest that for this particular genotype, a longer ageing period of 7 d may be required to optimize its effects on pork eating quality. These data indicate that the proteolytic enzyme activity on degradation of the myofibrillar lattice to improve tenderness was not optimized by 7 d. Interestingly, Channon *et al.* (2013), in a study comparing dietary treatment/age at slaughter and ageing period (7 or 28 d) in pigs of a different genotype, found no effect of ageing period on eating quality of loin steaks and silverside roasts. This suggested that proteolytic breakdown of the myofibrillar lattice had plateaued before 7 d post-slaughter.

On a cut level, stir fry samples obtained from the chuck tender located in the shoulder performed best, with highest scores for an overall fail rate of 5.3% for quality grade. Interestingly, in comparison to Channon *et al.* (2013) where 24.2% of evaluations for shoulder stir fry rated less than 3 for re-purchase intention, this was reduced to 8.8% in this study.

The sensory quality of the different cut x cooking methods was influenced by endpoint temperature. Loins cooked to 70°C had higher sensory scores than those cooked to 75°C. In this study, increasing the endpoint temperature from 70 to 75°C for loin steaks reduced juiciness (with overall liking nearing significance, P=0.056). This could be due to increased moisture loss as cooking loss from the loin was influenced by cooking temperature when samples were cooked in a water bath to either 70 or 75°C endpoint temperature for WB determination. In a study comparing the effect of endpoint temperature on quality of blade, loin and leg roasts containing the *semimembranosus* and *adductor* muscles, Heymann *et al.* (1990) also reported that moisture loss, increased as endpoint temperature increased. Overall, 25% of loin steaks evaluated by consumers were rated as either unacceptable or below average for quality and 35% of these steaks would not have been purchased again by consumers. In this study, cooking loin steaks to an endpoint temperature of 70°C reduced fail rate of loin steaks by 7.6% (28.8% and 21.2% fail rate for steaks cooked to 75 and 70°C, respectively). Although work is still required to define pathway parameters to lower fail rates of pork cuts to those found for cuts from the shoulder, it is recognised that communicating clear cooking messages to consumers to reduce the practice of overcooking of pork loin steaks is integral to the success of an eating quality program for pork – and of particular relevance for cuts that are not moisture infused.

Improved juiciness of the blade roast compared with loin and silverside roasts was found, which could potentially be due to lipid migration from melted intermuscular fat and/or more soluble collagen in the blade compared to the loin and silverside. This may also have contributed to higher scores for tenderness, overall liking, quality grade and re-purchase intention found for blade roasts compared with other roast cuts. However, intramuscular fat samples only included trimmed lean so these data cannot be used to explain potential differences between roasts from the different primals. The high performance of the *supraspinatus* muscle from the shoulder for stir frying was again confirmed in this study.

A number of studies have demonstrated that pork roasts cooked to 71°C were more preferred than those cooked to a higher temperature (>76°C) (Heymann *et al.*, 1990; Siemens *et al.*, 1990; Saunders *et al.*, 1999). In this study, it was not possible to recommend the optimal endpoint temperature for loin and silverside roasts to optimize consumer satisfaction based on fail rates for quality score. The fail rates for quality grade for loin roasts cooked to 70°C and 75°C were 19.4 and 20.0%, respectively. Small differences in fail rate were also found for the silverside when cooked to 70°C and 75°C (27.5 and 26.3%, respectively). The fail rate, based on quality grade score, of silverside roasts was 27%, whilst the fail rate for re-purchase intention was 35%. For roasts from the loin and blade, fail rates for quality score were 19 and 6%, respectively and those for re-purchase intention were 28% and 10%, respectively. As silversides and loins are commonly prepared as roasts, these results are of high concern.

None of the quality interventions imposed in this study resulted in consistent improvements in pork consistency. In terms of fail rates of pork, the main outcomes from this study include:

- No significant effect of gender on fail rate for either quality grade or re-purchase intention and none of the significant interaction terms included gender.
- For the shoulder:
  - Ageing for 7 d reduced fail rates of shoulder stir fry by 3.1% compared with ageing for 2 d, but was not significant (6.8 vs. 3.8%, respectively; P>0.05)
  - Cooking shoulder roasts to 75°C reduced the fail rate by 3.8% compared to 70°C.
  - Fail rates of stir fry was comparable to roasts for the shoulder primal, for both quality grade and re-purchase intention
  - Achieved average fail rate outcomes of <10% for both cuts from the shoulder, across gender, ageing period and endpoint temperature.
  - These results suggest that overall the shoulder performs well on an eating quality basis – market opportunities to improve the positioning of shoulder cuts need to be explored.
- For the loin:
  - Across all cuts, there was no clear gender effect on fail rate for quality grade identified
  - Cooking loin steaks to an endpoint temperature of 75°C increased the fail rate compared to cooking to 70°C (reflecting lower juiciness scores) and ageing for 7d post-slaughter reduced fail rate by 2.6% (26.3 and 23.8% for 2 and 7 d aged steaks, respectively).
  - Significant correlations between juiciness and cooking loss for both pork loin and stir fry reflect the negative impact of cooking to an endpoint temperature of 75°C, rather than 70°C, on moisture loss.
  - Fail rate of 7d aged loin steaks cooked to 70°C were lower across both genders.
  - Fail rate of 2.5% for 7 d aged stir fry cooked to 70°C for both entire and immunocastrated males.
  - High fail rate of 7d aged loin stir fry cooked to 75°C for both genders (25% and 15% for entire and immunocastrated males, respectively)
  - Fail rate of 7d aged loin roasts was high (37.5-40%) when cooked to either 70 or 75°C for both genders.
  - Cooking loin as stir fry pieces resulted in lower fail rates than when cooked as a roast
  - *Implementation of pathway systems to maximise eating quality acceptability of loin steaks is of paramount importance given their poor performance in this study.*
  - *Re-purchase intention fail rates were high for all loin cuts evaluated in this study.*
- For the silverside:
  - Highest fail rates were found for silverside roasts, followed by loin steak and silverside stir fry
  - Higher fail rate for entire males for silverside stir fry aged for 2 d than from immunocastrates was observed (30% v. 12.5%, respectively). The repeatability of this gender effect needs to be further validated to determine if it is real.

- *Further work is required to determine those interventions that can improve overall eating quality performance of silversides, especially but not limited to when cooked as roasts, given that leg roasts typically include the silverside primal.*

As concluded by Channon *et al.* (2013), different pathway parameters still need to be evaluated to result in the production of pork cuts of consistently high quality. Based on outcomes from this study, and previous Pork CRC funded eating quality work, continued focus is required on roasts and steaks from the loin and leg to reduce fail rates. This will be further investigated within the new Pork CRC funded validation study that is proposed to include hanging carcases from the aitchbone or electrical stimulation and ageing as well as a positive control of moisture infusion on eating quality attributes of loin steaks and silverside roasts. Meat Standards Australia includes aitchbone hanging for both beef and sheep meat as a quality intervention to improve quality consistency.

5 Conclusions and Recommendations

This study provided comparative information on the effects of ageing period, endpoint temperature, cut type and cooking method for the immunocastrated male, compared with entire males, and extended outcomes from the study that involved entire males, females and surgical castrates (Channon *et al.* 2013). Unlike Channon *et al.* (2013) who observed small eating quality differences between entire males and surgical castrates (which were also anticipated between immunocastrated and entire males), no gender effects on eating quality were found in this study. The lack of effect of gender could be explained by low, and less variable, androstenone and skatole levels present in entire males in this study and differences in consumers involved in both studies. Although this outcome may suggest that pork from entire males may be suitable for inclusion into an eating quality system for Australian pork, it was found that 25% of the entire males in this study had levels of androstenone > 1µg/g and of these, two animals were classified as having boar taint. This highlights the risk of boar taint in entire male carcases within the hot carcase weight range of 60-75 kg. Given that the hot carcase weight of Australian pork is slowly increasing, this risk of boar taint will increase if immunocastration is not adopted.

The targeted fail rate of <10% was achieved for both the shoulder stir fry and roast for both quality grade score and re-purchase intention. Higher fail rates were again observed for re-purchase intention than for quality grade and these are similar in magnitude to those previously reported by Channon *et al.* (2013). Knowledge of what attributes are required for pork to be more positively rated by consumers for re-purchase intention is required to assist with improving re-purchase intention scores.

- Ageing different pork cuts for 7 d was not sufficient to result in improved eating quality. This is in contrast to a study conducted with another genotype where no difference in eating quality traits following ageing for 7 or 28 d were found (Channon *et al.* 2013), together with lower fail rates for both loin steaks and silversides (11.5% and 22.6%, respectively).
- This indicates that the application of outcomes arising from this study will need to validated across different supply chains and, potentially, further modifications made to pathway interventions implemented by these supply chains in order to deliver pork of consistently high quality to their customers.
- Although it was demonstrated that pork from entire males in this study was as acceptable to consumers as pork from immunocastrates, boar taint was still identified in 10% of the entire males in this study and in total, 25% of entire males had high levels of androstenone.

- Demographic data was not found to explain consumer scores for overall liking.
- These outcomes suggest that further work is still required to reduce fail rates of pork from immunocastrated males.
- Cooking pork steaks to 75°C was demonstrated to reduce juiciness and overall liking scores compared to cooking to an endpoint temperature of 70°C.
- It was again demonstrated that the development of a cuts based eating quality for pork cannot be based primarily on the loin muscle, even if cooked in different ways, given that fail rates of different cuts cooked as roasts or stir fry were not similar.
- Quality grade and re-purchase intention scores obtained for pork in this study, together with the percentage of evaluations that achieved scores of either 1 or 2 and referred to as 'fail rate' for quality grade and 'would not buy' for re-purchase intention showed that the Australian pork industry still has significant quality issues to overcome in order to achieve our objective of a fail rate of <10% across all cuts available to consumers.
- Cooking education is recommended, focused on retailers and consumers to provide information on cooking practices to optimize performance of different pork cuts.

The next phase of this work will focus on validating additional interventions to refine proposed eating quality pathways aimed at delivering consistent quality pork to consumers. Analyses will also be conducted to determine whether the interventions imposed change proportions within each quality grade in our efforts to produce premium quality pork.

The proposed methodology will involve testing of a number of scenarios to address:

- Ageing period (and other interventions) required to shift different cuts from good, everyday to premium;
- Use of aitchbone hanging coupled with ageing period
- Recommended chilling practices – pH/temperature windows achieved and what interventions are required to overcome issues with rapid chilling
- Electrical stimulation - use of electrical stimulation for pork carcases will require additional work to demonstrate that shrinkage loss is not influenced by low voltage constant current electrical stimulation.
- It is anticipated that when options are explored they will result in the Australian pork industry not being fully reliant on the use of moisture infusion (that will be included in the study as a positive control) as an effective mechanism to supply premium grade pork.

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