Development of an eating quality system for the Australian pork industry

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Abstract— **Tenderness, juiciness and flavour are the key eating quality attributes that influence consumer appreciation of pork, but there is no simple 'on-line', low cost tool available to industry to grade carcases for these traits. Previous research has determined and documented the importance of a number of pre- and post-slaughter management factors on the eating quality of pork, but this information has not been integrated into an eating quality system. The objective of this project is to develop a cuts-based eating quality assurance system, with clearly defined production pathways from production to consumption, to enable the Australian pork industry to supply customers with consistently high quality pork. Key critical control points have been quantified from this initial work on non-prescriptive predictive models for pork eating quality.**

Keywords— **pork, eating quality, model.**

I. INTRODUCTION

The Australian pork industry recognises the importance of consistently delivering pork and pork products of high eating quality to consumers and has been included as a Strategy within Australian Pork Limited's 2010-2015 Strategic Plan. Channon et al. [1] identified that achieving cut-off scores for consumer acceptability may be difficult to attain, given that only 35% of grilled pork steaks achieved average consumer scores of 60 or higher for tenderness and 49% for juiciness, flavour and overall liking.

In contrast to the red meat industry where the MSA grading system has been implemented to predict eating quality [2], the Australian pork industry has relatively underdeveloped systems for the systematic prediction of pork eating quality.

An extensive review on pathway factors that can influence pork quality was recently published [3]. This study attempted to quantify the impact of key critical control points using a pathway approach that can influence eating quality attributes of fresh pork, with a view to implementing pathway interventions to improve the consistency of pork eating quality.

II. MATERIALS AND METHODS

This study involved the compilation of an extensive database of previous research that reported effects on pork eating quality. The majority of studies were obtained from peer-reviewed journals and several unpublished final reports from previous Australian pork quality research [1, 4]. All publications were assessed for rigour prior to inclusion into the database. The database contains details of experimental treatments in rows and data of the measured variables in columns. All sensory data was converted to a 0-100 scale, with 0 indicating extremely tough, dry, poor flavour and 100 indicating extremely tender, juicy and excellent flavour. Given that sensory data were averaged across a number of consumers/trained taste panellists, data ranged from 30–80 on a scale of 0–100 and did not cover the full range of 0–100.

The analysis approach taken was to arbitrarily set parameters for a 'standard' Australian pig (Table 1). Linear and non-linear regression analysis (using a three parameter equation $y_0= a/(1+\exp(-(x-x_0)/b)))$ were undertaken using SigmaPlot 12 (Systat Software Inc. Germany) of single-order relationships comparing different variables within each parameter with that for the 'standard' pig for sensory tenderness, flavour and juiciness. No studies met all the criteria for the Australian 'standard' pig.

To assist with further analysis, genotype was pooled into three major groups (White, Duroc-sired and Hampshire sired) with insufficient data available comparing other genotypes (e.g. Pietrain, Berkshire etc.) with White-sired pigs. Final endpoint internal temperatures and ageing period were also pooled. Only paired data within a study for each parameter was used; all other factors investigated within each study, other than those in question, were not taken into account in the analysis. For studies that presented data from factorial designed experiments, paired data within treatments were used. As limited data were available for interactions, the effect of different treatment interactions on sensory quality could not be determined. Due to lack of data, not all comparisons could be made within each parameter.

Table 1: Parameters of the ‘standard’ Australian pig

Parameter	Variable (x)	Comparative variables (y_0)
Sex	Female	Entire male, Surgical castrate, immunocastrate
Genotype group	White	Duroc-sired, Hampshire sired
Halothane gene	Normal (NN)	Nn, nn
Housing	Indoor/conventional	Outdoor
Nutrition	*ad libitum*	Restricted
Metabolic modifiers	None	pST, ractopamine
Handling	Minimal	Negative
Mixing	not mixed	Mixed
Stunning	CO_2	Electrical
Ageing period	1-2 days	3-5 days, 6 to 10 days, > 11 days
Moisture infusion	None	moisture infusion
Final internal temperature	70-74°C	65-69°C, 75-79°C, ≥80°C
Cooking method	Grill	Roast, Fry

III. RESULTS

Linear regression models implied that gender, genotype class, halothane gene, nutritional management and the use of metabolic modifiers, ageing period, moisture infusion, internal temperature, cooking method and muscle influenced eating quality attributes when compared with the variables set for the ‘standard’ pig. The amount of variation explained by the linear and non-linear regression equations (data not presented) was similar for the effect of various production, processing, post-slaughter and cooking factors on eating quality attributes (namely tenderness, flavour and juiciness).

Predicted means for comparative variables, prediction intervals and R^2 for each linear regression equation when solved for each x variable = 50 are shown in Table 2. The effects of production factors were shown to be of lesser importance compared with post-slaughter effects on sensory scores. Lack of sensory data for pre-slaughter factors (e.g. mixing, handling, transport) did not allow analyses to be conducted. The relationship between CO_2 and electrical stunning for all sensory attributes was low (R^2 0.05).

The effect of gender on aroma was not possible to evaluate given that few studies investigating boar taint with sensory results have included females.

IV. DISCUSSION

A. Gender

This study highlighted that more data are required to better quantify the relationship between immunocastrated males and females. Although this analysis suggested that pork from immunocastrated males would be more acceptable in eating quality than females, this analysis was only based on four to six paired data points. Differences in sensory attributes between the four gender classes may reflect differences in intramuscular fat content and composition, protein deposition rates as well as the presence of boar taint. Interactions between gender and nutritional management (including the use of metabolic modifiers) on eating quality do exist but the extent of these interactions are difficult to estimate, as few studies report effects on eating quality in addition to growth performance, carcase composition and fatty acid composition effects. Consideration of interactions with genotype, nutrition and other environmental effects are also required.

B. Genetic factors

Although genotypic differences between White and Duroc and Hampshire sired pigs were found in this study, Australian pig breeders have limited knowledge of the relative merit of individual sires or sire breeds on meat and eating quality traits [5], so commercial producers have limited ability to make informed choices of sire selection to improve eating quality characteristics. Several studies [6, 7] concluded that there is less opportunity to improve eating quality traits, such as flavour and juiciness, through line selection, whilst sire breed group x gender interactions were not found for any quality attribute investigated, other than HSCW[5].

The presence of the halothane gene was shown to negatively impact on juiciness and flavour, reflecting the effect of fast glycolytic rate on water holding capacity and low ultimate pH on juiciness and acidic/sour flavour, respectively, and this was confirmed in this analysis. The contribution of low ultimate pH to inconsistent pork eating quality is an area for further work given that there is neither no established pH/muscle temperature window nor ultimate pH cut-offs developed to optimise eating quality of pork, unlike beef and lamb.

C. Animal management

Linear regression analysis showed that pST resulted in a 5.3% reduction in sensory tenderness, 2.4% reduction in flavour and 1% improvement in juiciness compared with control pigs. The inclusion of ractopamine (5-10 ppm) in feed reduced sensory tenderness by 7.2% and flavour and juiciness by about 1%. These outcomes compare favourably with those previously reported [8]. Due to lack of available data it was not possible to determine interactions with other parameters including gender, genotype or nutritional management. No interaction was found between the use of ractopamine and/or pST and moisture infusion post-slaughter on sensory pork quality [9]. Feeding pigs on a restricted diet compared to *ad libitum* pre-slaughter was found to result in a 4.2% reduction in tenderness due to a decrease in protein turnover rates.

D. Post-slaughter management

When compared with other pathway parameters, moisture infusion had the greatest impact on sensory tenderness and juiciness, followed by ageing for 6-10 days post-slaughter. Fail rates of pork were significantly reduced by moisture infusion [10]. The interaction between moisture infusion and ageing period was not significant for any of the sensory attributes assessed by consumers, except sensory tenderness [9], whilst the interaction term of hanging method x ageing period was not significant for sensory quality of the loin and topside muscle [1]. Also, no interaction between Duroc content and ageing period of female pigs for sensory quality was found [11]. This suggests that the inclusion of moisture infusion, hanging method and ageing period into a pathway model to improve pork sensory quality could each be additive factors. Individual equations generated in this study cannot be used as multiplicative factors to account for situations where a number of quality interventions are imposed, given the statistical complexity in accounting for standard errors associated with each equation. Hanging method and electrical stimulation was not evaluated as potential interventions to improve eating quality in this current analysis, given that they are not favourably viewed by Australian processors.

E. Cooking method, final internal temperature and muscle

Overcooking of pork by consumers and its impact on quality remains an important issue to address. Interactions between cooking method, final internal temperature, cut type and muscle on pork eating quality were not elucidated from the literature. Many studies have only reported effects on the *longissimus* whilst variations in connective tissue content and solubility, intramuscular fat content and composition and ultimate pH can also influence sensory quality of cooked pork. To enable the system to be cuts-based rather than carcase-based, these relationships need to be better understood and quantified, as well as interactions between muscles aged for different periods from different genders, to fill knowledge gaps.

V. CONCLUSIONS

The development of a non-prescriptive eating quality assurance system with two levels – standard and graded/eating quality assured is underway. It is envisaged that the system will be flexible, allow industry to improve overall perception of pork as a quality meat and lead to a process of continuous improvement in pork eating quality as goal posts in the future continue to shift. Such an approach could also allow companies to individually determine which pathway interventions are imposed for targeted markets. It is acknowledged that the analyses conducted to date has limitations, but was useful in identifying key critical control points, knowledge gaps and framing further work required in this area in the development of an eating quality system for Australian pork. Further sensory work, particularly including quality grades, re-purchase intention and willingness to pay, will provide opportunity to quantify the extent to which quality can be shifted by implementation of particular pathway interventions.

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Table 2: Predicted means (y_0), 95% prediction intervals (PI) and variation explained by linear regression equations for key parameters, solved for x (in brackets) values of 50, for sensory tenderness, flavour and juiciness

	Tenderness			Flavour			Juiciness		
Parameter	y_0	95% PI	R^2	y_0	95% PI	R^2	y_0	95% PI	R^2
Gender (Female)									
Surgical castrate	52.47	42.08, 62.87	0.68	54.28	43.28, 65.29	0.87	50.80	41.35, 60.25	0.78
Entire male	50.34	41.99, 58.68	0.73	49.60	44.13, 55.07	0.94	50.84	45.73, 55.96	0.85
Immunocastrate	59.81	46.94, 72.68	0.86	57.19	52.03, 62.35	0.92	54.65	29.13, 80.17	0.90
Genotype group (White)									
Duroc sired	46.89	35.29, 58.48	0.82	50.98	45.90, 56.06	0.97	51.62	42.90, 60.35	0.74
Hampshire sired	54.47	39.44, 69.49	0.43	51.92	47.53, 56.32	0.98	54.74	38.93, 70.54	0.41
Halothane gene (NN)									
Nn	52.90	42.71, 63.09	0.62	50.49	46.83, 54.16	0.97	47.48	39.01, 55.95	0.88
nn	48.86	29.44, 68.29	0.47	46.46	30.20, 62.72	0.84	42.70	28.11, 57.30	0.69
Feeding level (ad libitum)									
Restricted	47.88	40.85, 54.91	0.98	48.70	45.84, 51.56	0.99	49.39	43.84, 54.94	0.98
Metabolic modifiers (none)									
pST	47.34	35.83, 58.85	0.83	48.79	40.91, 56.66	0.88	48.36	36.63, 60.08	0.72
Ractopamine	46.39	36.30, 56.47	0.79	49.47	42.85, 56.09	0.98	49.54	39.52, 59.56	0.72
Moisture infusion (no MI)									
MI	62.94	48.55, 77.33	0.46	52.10	35.35, 68.85	0.81	60.27	46.03, 74.51	0.66
Ageing period (1-2 days)									
6 to 10 days	57.86	48.50, 67.21	0.70	55.98	50.22, 61.73	0.79	55.92	46.45, 65.39	0.35