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Estimating the impact of various pathway parameters on tenderness, flavour and juiciness of pork using Monte Carlo simulation methods

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ABSTRACT

Monte Carlo simulation was investigated as a potential methodology to estimate sensory tenderness, flavour and juiciness scores of pork following the implementation of key pathway interventions known to influence eating quality. Correction factors were established using mean data from published studies investigating key production, processing and cooking parameters. Probability distributions of correction factors were developed for single pathway parameters only, due to lack of interaction data. Except for moisture infusion, ageing period, aitchbone hanging and cooking pork to an internal temperature of >74 °C, only small shifts in the mean of the probability distributions of correction factors were observed for the majority of pathway parameters investigated in this study. Output distributions of sensory scores, generated from Monte Carlo simulations of input distributions of correction factors and for individual pigs, indicated that this methodology may be useful in estimating both the shift and variability in pork eating traits when different pathway interventions are applied.

1. Introduction

From a mechanistic point of view, the manipulation of biochemical and physical factors through conditions imposed on an animal throughout its life, on carcases and on different muscles post-slaughter can collectively contribute to eating quality, upon consumption. It is well recognised that sensory attributes of pork, namely tenderness, flavour and juiciness, can be influenced by: the rate and extent of muscle pH decline and resultant effects on ultimate pH, water holding capacity, colour, drip loss and proteolytic enzyme activity; gender due to the presence of boar taint in entire male pigs; fatty acid composition, connective tissue content and solubility, myofibrillar structure and intramuscular fat content. Many qualitative reviews have been published (e.g. Babol & Squires, 1995; Bonneau & Lebret, 2010; Channon & Warner, 2011; Ngapo & Gariepy, 2008; Rosenvold & Andersen, 2003; Wood et al., 2008) that have comprehensively detailed the impact of the large number of production, pre-slaughter, post-slaughter and cooking parameters on pork eating quality. A number of meta-analyses have also quantified the effects of metabolic modifiers including pST and ractopamine (Dunshea, D'Souza, Pethick, Harper, & Warner, 2005), halothane gene (Salmi et al., 2010), gender (in combination with breed and carcase weight) (Trefan, Doeschl-Wilson, Rooke, Terlouw, & Bünger, 2013), housing (Demori et al., 2012), Vitamin E administration (Trefan et al., 2010) and fasting, transport and lairage (Salmi et al., 2012) on sensory and meat quality parameters of pork. However, unlike the Meat Standards Australia eating quality pathway systems for beef (Watson, Polkinghorne, & Thompson, 2008) and sheepmeat (Pleasants, Thompson, & Pethick, 2005), there has been no attempt to develop prediction models that, when implemented by industry, will enable pork to be supplied to consumers to be of consistently high eating quality.

Domestically, the Australian pork industry faces strong competition with other meats, particularly with increasing supply of Meat Standards Australia-graded beef and lamb at the retail and food service level in Australia and strong consumer confidence with chicken. The ability of the Australian pork industry to deliver consistent, high quality pork products to consumers is paramount to increase consumer satisfaction with pork and drive consumption frequency (Anon, 2014). A system that can deliver consistently high quality pork to domestic customers may also have application in supporting industry market development endeavours to supply Australian pork products of high integrity to niche, high value export markets in Asia (Channon & Warner, 2011). However, any system developed needs to be flexible and non-prescriptive to enable different commercial companies to utilise alternative approaches to deliver consistently high quality pork to their customers. An alternative approach to meta-analysis to quantify the size, effect and variability on pork eating quality traits due to the implementation of different pathway parameters from production to consumption, and their interactions, was explored in this study.

Monte Carlo simulation analyses are used to analyse and investigate various sources of risk and uncertainty and are being applied in fields including financial modelling, project management and quantitative

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microbial risk assessment (Vose, 2008). Whilst this approach may have potential as a technique to assist with quantifying risks to pork eating quality attributes due to the various pathway factors experienced by pigs, carcases and pork from production to consumption, no precedents were available to understand the distribution of probability estimates for the effects on eating quality resulting from effects of different factors experienced by animals, carcases and meat along the pork supply chain. This study aimed to establish whether probability distributions of correction factors can be effectively used to estimate effects of various pathway factors on eating quality of pork, based on quantitative outcomes from existing literature.

The hypothesis of this study was that correction factors, established by determining relative changes in sensory tenderness, juiciness and flavour scores of pork in response to pathway parameters imposed on pigs, carcases and/or pork cuts, would be useful, quantifiable indicators of pork eating quality. In utilising such an approach, a high degree of variability in these correction factors was anticipated, reflecting the significant diversity in experimental designs, treatments applied and the number of studies conducted that have reported effects of nominated pathway parameters on pork eating quality. It was considered that the representation of these correction factors as probability distributions may allow this uncertainty to be expressed with Monte Carlo simulation methods then applied by industry risk managers to determine effects of different pathway interventions on pork eating quality and to manage such risks accordingly.

2. Materials and methods

This study involved the compilation of a database of research reporting data for effects of production, pre-slaughter, post-slaughter and cooking parameters on pork eating quality, assessed by both inexperienced consumers or trained/experienced panellists, and objective measurements. The majority of studies were obtained from peer-reviewed journals, together with several unpublished final reports from previous Australian pork quality research (Campbell, 1998; D'Souza & Moore, 2005; Laing, 1996; Saunders, Cumarasamy, & Hedderley, 1999; Saunders, Wilkinson, & Hall, 2000; Wilkinson, 2002) identified from extensive systematic literature searches of different digital databases. All publications were assessed for experimental rigour prior to inclusion into the database. Details of experimental treatments were entered in rows and data of reported variables in columns. The database included details of each reference including author's name, publication year, country of study, animals/cuts per treatment, animals used (including gender, genotype, liveweight, carcase weight, fatness), sensory panel description (trained/experienced or consumer), experimental treatments imposed, design details, statistical analyses (mean value, standard deviation/standard error), muscles and cuts used, objective and subjective quality data. The database comprised of 328 articles, published between 1968 and 2015. When compiling this database, a number of groupings were made within each factor being assessed to assist with the analysis. For example, pigs described in the literature as being Landrace, Large White and/or Yorkshire were categorised as White. Different sub-datafiles were used for each attribute under investigation due to the requirement that each attribute under investigation needed to be described in the study methodology for the study to be included. As data were reported using differing scales, all sensory data was converted to a 0 (very tough, very dry, dislike extremely/bland flavour) to 100 scale (very tender, very juicy, like extremely/strong flavour) and shear force data converted to Newtons. As sensory data were mean data, data ranged from 30–80 on a scale of 0–100 and did not cover the full range of 0–100. For flavour, hedonic scores were primarily utilised in the construction of the normal probability distributions of correction factors. Studies that reported overall acceptability scores, together with intensity scores for flavour, were also utilised, only where overall acceptability scores could be used to infer the impact of the experimental treatment(s) on flavour intensity. Flavour intensity data was also utilised from studies that did not assess overall acceptability but reported positive correlations between flavour and tenderness and/or juiciness scores (e.g. Alonso, Campo, Provincial, Roncalés, & Beltrán, 2010; Bereskin, Rough, & Davey, 1978) and/or where increases in magnitude were favourably viewed (e.g. Barton Gade, 1998; Bérard, Kreuzer, & Bee, 2010; Boles, Parrish, Skaggs, & Christian, 1991; Candek-Potokar, Zlender, & Bonneau, 1998; Hansen, Claudi-Magnussen, Jensen, & Andersen, 2006; Heymann, Hedrick, Karrasch, Eggeman, & Ellersieck, 1990; Juárez et al., 2009; Wood, Nute, Fursey, & Cuthbertson, 1995). Only studies that assessed flavour using hedonic scales were used to estimate the effect of gender on flavour, given that higher flavour intensity scores may reflect boar taint issues, rather than be a positive attribute. Furthermore, when flavour intensity scores were utilised from studies conducted with trained panels, only those pertaining to 'pork flavour' not 'abnormal flavour' or 'off-flavours' were used. To enable comparisons to be made, variables for each pathway parameter investigated were arbitrarily set for a 'standard pig' (Table 1); noting that no studies in the database contained data that enable all comparisons for a 'standard' pig to be made from a single study. As an example, for gender the 'standard' pig was determined to be female, given the various management decisions available to producers to manage risks associated with boar taint, growth performance and/or customer specifications of male animals – only those studies that reported eating quality effects between females and different male genders (physical castrates, entire males and/or immunocastrated males) were included – studies that did not include a female comparison were not used. Relevant studies from the large database were identified and smaller data files were then created for each factor, where there was sufficient data. These datafiles only included studies that had investigated effects of each specific pathway parameter and must have reported sensory outcomes (for tenderness, juiciness, flavour) and/or shear force, as an objective measure of tenderness, for one or more of the comparisons shown in Table 1. The proportional change of each attribute in comparison to the parameter set for the 'standard' pig for that attribute was then determined by dividing the mean for the comparative variable by the mean data for the 'standard' pig variable. Correction factors for each of the standard pig specifications were therefore set at 1. For this analysis, it was not necessary to determine whether each factor under investigation significantly influenced the particular eating quality attribute.

For this analysis, due primarily to lack of studies that have reported interaction effects of different pathway parameters in relation to the

Table 1
Arbitrary variables of the Australian 'standard' pig set for each key pathway parameter.

Pathway parameter	Variable (x)	Comparative variables (y_0)
Gender	Female	Entire male, physical castrate, immunocastrated male
Genotype	White	≥50% Duroc, Pietrain, Hampshire, Berkshire
Halothane gene	Normal (NN)	Heterozygote (Nn), homozygous recessive (nn)
Housing	Indoor/conventional	Outdoor, Straw bedding
Plane of nutrition	ad libitum	Restricted
Metabolic modifiers	None	pST, ractopamine
Mixing	Not mixed	Mixed
Stunning method	CO_2	Electrical
Electrical stimulation	No	Yes
Ageing period	1–2 days	3–7 days, >7 days
Hanging method	Achilles	Aitchbone (tenderstretch)
Moisture infusion	None	Moisture infusion
Final internal temperature	70–74 °C	<70 °C, >74 °C
Intramuscular fat content	<1.6%	>1.6%
Ultimate pH	5.5–5.7	<5.5, >5.7