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Review

Modelling quality variations in commercial Ontario pork production

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ABSTRACT

This study explores the interactions of sensory and nutritional environment with genotype occurring in current commercial pork production in Ontario, Canada, which may interact to result in poor quality meat. The study focussed on identifying factors and signalling mechanisms that contribute to poor meat quality, in order to develop strategies to reduce the incidence of unacceptable product quality. In the first phase of the work reported here, animal behaviour and muscle metabolism studies were related to meat colour, tenderness and water-holding capacity measurements from commercially-produced pigs killed in a commercial packing plant. A partial least squares analysis was used to determine the most important of the principal production variables, peri-mortem biochemical measures and post-mortem carcass condition variables studied, in terms of their influence on water-holding, toughness and colour (L^*-value). Variations between producer and kill day at the slaughterhouse were very strong contributors to variability in these three meat quality parameters, followed by pH variations. A second phase of the study is currently underway to characterize patterns of gene expression related to extremes of end-product quality and to reduce quality variations by nutritional and behavioural management strategies.

Contents

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1. Introduction

Canada produced 23.4 million pigs for domestic slaughter and live export in 2006 (Canadian Meat Council, 2008; Canadian Pork Council, 2008). Export of pork meat in 2006 was over 1.03 million tonnes, with exports to the USA and Japan accounting for more than half this figure. With such a strong dependence on export, Canada needs to remain competitive in the global marketplace and therefore must focus on producing a quality product that meets customer demands. Based on genetic and management improvement, Canadian pork has been getting leaner while being produced more efficiently. The Canadian centre for swine improvement (CCSI, 2004) reports a decrease of 8.9 days to market, 131 fewer grams of feed per kg of weight gain, 1.7 mm less backfat, and 1.5 cm^2 more loin eye area in genetic progress of Canadian purebred breeding stock in the previous six years alone. These characteristics have all helped the production sector by improving lean growth efficiency, with loin eye area and backfat being the only traits considered in regards to product quality. Recently, more attention has been focused on improving traits specifically related to meat quality such as colour, water-holding capacity (drip loss), tenderness, and intramuscular fat (IMF) content. The meat packing industry is moving towards specialized grading grids that often include specific targets for carcass weight, backfat depth, lean yield, loin eye area, marbling (IMF) and colour. It is generally accepted that the average carcass is of acceptable quality but there is a wide variation in carcass quality and a significant number of carcasses not meeting acceptable quality standards.

Pork meat quality is affected by numerous factors including breed, genotype, feeding, pre-slaughter handling, stunning and slaughter practices, chilling, and storage conditions (Rosenvold & Andersen, 2003; Schäfer, Rosenvold, Purslow, Andersen, & Henckel, 2002). While many of these factors have been studied in isolation, interactions among these factors are poorly understood (Warriss et al., 1998). Pork quality is the result of a complex combination of factors, with interactions among the sensory environment, genotype and nutritional environment combining with peri-mortem metabolism to influence final meat quality.

1.1. Behavioural factors

Numerous studies have demonstrated the relationship between behavioural and physiological measures of stress in pigs at slaughter and subsequent effects on meat quality, particularly pale, soft and exudative (PSE) pork (Hemsworth et al., 2002; Warriss et al., 1998). It is widely recognized that the shipment and handling of pigs prior to slaughter causes significant stress to animals (Guise & Penny, 1989), and that individual responses to pre-slaughter stress vary considerably (Grandin, 1997). In terms of meat quality, stress-susceptibility has been mainly identified at the level of the muscle, specifically in mutations in the skeletal ryanodine receptor (sRyR) known to cause porcine stress syndrome (Fujii et al., 1991). However, differences in stress-susceptibility may also occur in areas of the brain responsible for emotional and neuroendocrine responses to stress. In rodent models, reductions in fear reactivity are characterized by lower corticotrophin-releasing factor mRNA expression in the paraventricular nucleus of the hypothalamus and higher numbers of glucocorticoid receptors in the hippocampus, which enhances negative feedback mechanisms of the hypothalamic–pituitary–adrenal (HPA) response to stress (Meaney, 2001). Boars heterozygous for the sRyR gene do not show differences in glucocortiocid receptor levels in the brain or stressor-induced HPA activation compared to wild type boars (Weaver, Dixon, & Schaefer, 2000a). However, variations in fear reactivity associated with differences in HPA function have been demonstrated in other lines of pigs (Weaver, Aherne, Meaney, Schaefer, & Dixon, 2000b). Therefore, variation in stress-susceptibility may be due to two separate mechanisms – at the muscle and at the brain. Behavioural stress responses are influenced by genetics, management and previous experience. Therefore, what is considered aversive by some animals may not produce a negative reaction in others. For example, Scott, Torrey, Stewart, and Weaver (2000) demonstrated that a genetic line of pigs selected for high lean growth showed increased anxiety in response to humans. Similar observations are reported by Grandin (1997), and associations between animal temperament and meat quality have also been observed in cattle (Petherick, Holroyd, Doogan, & Venus, 2002). Provision of environmental enrichment and/or positive interactions with humans on the farm can attenuate fearfulness and reduce stress at shipment and pre-slaughter (Beattie, O'Connell, & Moss, 2000; Geverink et al., 1998; Hill, McGlone, Fullwood, & Miller, 1998). In addition, it has been suggested that genetic and management factors can act synergistically to increase stress responses, thereby reducing meat quality (D'Souza, Dunshea, Leury, & Warner, 1998a). The relationships among individual differences in fear response, HPA activity and any consequent effects on meat quality have not been explored to date.

1.2. Nutritional factors

Modification of hog finishing diets can significantly impact water-holding capacity and eating quality of pork as noted in past reviews (Rosenvold & Andersen, 2003; Warriss et al., 1998). Researchers have investigated numerous dietary factors that influence meat quality, including protein quality and amino acid balance, protein to energy ratios, type of carbohydrates, fat quality, betaine, creatine, niacin, α-tochopherol, types of magnesium, vitamins E and C, glycolytic inhibitors and ractopamine among others (Apple, 2007; Apple, Maxwell, Stivarius, Rakes, & Johnson, 2002; Caine, Schaefer, Aalhus, & Dugan, 2000; D'Souza, Warner, Leury, & Dunshea, 1998b; Frederick, van Heugten, & See, 2004; Hamilton et al., 2002; Matthews, Southern, Bidner, & Persica, 2001; Peeters, Driessen, Steegmans, Henot, & Geers, 2004; Real et al., 2002; Stahl, Allee, & Berg, 2001). The impact of dietary interventions on pork meat quality has, in most cases, not been consistent across studies. This is largely due to interactions between various factors that influence pork meat quality – especially pig genotype and pre-slaughter stress – which have not been considered or are poorly understood (Warriss et al., 1998). However, a more complete understanding of the underlying mechanisms that influence pork meat quality could lead to the development of effective feeding and animal management strategies to enhance pork meat quality and reduce its variability.

Reducing muscle glycogen stores in pigs at slaughter can improve water-holding capacity and overall eating quality of pork meat, by preventing excess lactic acid production in muscle around the time of slaughter (Rosenvold et al., 2002). Muscle glycogen stores can be reduced by feeding diets that are low in glucogenic carbohydrates such as starch and sugars. The post-mortem generation of excess amounts of lactic acid from glycogen, induced by responses to external stressors and feeding adrenergic agonists (ractopamine), can increase the rate and extent of pH decline in muscle with subsequent negative effects on various aspects pork meat quality, including light meat color and reduced water-holding capacity (Rosenvold et al., 2002), especially in stress susceptible pigs. However, the impact of medium doses of ractopamine on pork meat quality has been small, somewhat inconsistent across studies, and is influenced by level and duration of feeding ractopamine, pig type and dietary protein level (e.g. Aalhus, Schaefer, Murral, & Jones, 1992; Armstrong, Ivers, Wagner, & Anderson, 2004; Uttaro et al., 1993). A recent study indicated that pigs fed