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Predicting beef cuts composition, fatty acids and meat quality characteristics by spiral computed tomography

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ABSTRACT

The potential of X-ray computed tomography (CT) as a predictor of cuts composition and meat quality traits using a multivariate calibration method (partial least square regression, PLSR) was investigated in beef cattle. Sirloins from 88 crossbred Aberdeen Angus (AAx) and 106 Limousin (LIMx) cattle were scanned using spiral CT. Subsequently, they were dissected and analyzed for technological and sensory parameters, as well as for intramuscular fat (IMF) content and fatty acid composition. CT-PLSR calibrations, tested by cross-validation, were able to predict with high accuracy the subcutaneous fat (R^2, RMSECV = 0.94, 34.60 g and 0.92, 34.46 g), intermuscular fat (R^2, RMSECV = 0.81, 161.54 g and 0.86, 42.16 g), total fat (R^2, RMSECV = 0.89, 65.96 g and 0.93, 48.35 g) and muscle content (R^2, RMSECV = 0.99, 58.55 g and 0.97, 57.45 g) in AAx and LIMx samples, respectively. Accurate CT predictions were found for fatty acid profile (R^2 = 0.61–0.75) and intramuscular fat content (R^2 = 0.71–0.76) in both sire breeds. However, low to very low accuracies were obtained for technological and sensory traits with R^2 ranged from 0.01 to 0.26. The image analysis evaluated provides the basis for an alternative approach to deliver very accurate predictions of cuts composition, IMF content and fatty acid profile with lower costs than the reference methods (dissection, chemical analysis), without damaging or depreciating the beef cuts.

1. Introduction

Consumers prefer leaner meat with the minimal fat level required to maintain juiciness and flavour, a preference thought to be due to health concerns (Ngapo, Martin, & Dransfield, 2007). In addition, consistent quality, less wastage, convenience and ease in cooking and high level of choice or flexibility in available cuts are of concern to consumers (Aaslyng, 2009). Hence, cattle breeders need to address carcass composition and meat quality traits, which will determine consumer acceptance of beef. Overall, meat quality is difficult to define because it is a combination of microbiological, nutritional, technological and organoleptic components. Moreover, the term “quality” of carcasses has different meanings depending on local customs in different countries of the world (Hocquette & Gigli, 2005). Hence, it becomes necessary to move focus from the aggregate “quality” to investigate individual components of meat quality, such as visual aspects (e.g. the colour of lean) or eating quality (tenderness, juiciness and flavour), which in turn are affected by intramuscular fat and fatty acid composition (Aaslyng, 2009).

Measurements of meat quality traits present particular problems for improvement, as direct measurements require destruction of the sample. Muscle quality is generally considered to be difficult, if not impossible, to measure in the live animal and is expensive and time-consuming to measure completely in samples from the carcass (Clutter, 1995). Tools to predict carcass composition for grading and classification of carcasses generally use dissected composition as a reference, which is usually obtained by manual dissection performed by skilled technicians. Beside the valuable and accurate information provided, it is also a destructive, time-consuming and therefore a costly method. Hence these methods are difficult and expensive to use in research programmes or breeding programmes involving many animals, and impossible to use routinely in commercial operations (Kempster et al., 1982).

Because of these restrictions, alternative methods have been used in beef cattle to predict meat quality attributes, such as near infrared (NIR) spectroscopy (Andrés et al., 2007; Prieto, Andrés, Giráldez, Mantecón, & Lavín, 2008; Prieto, Ross, et al., 2009). Moreover, partial dissection using sample joints (Kempster & Jones, 1977), visual assessment of fatness and conformation (Kempster et al., 1982), ultrasound scanning in live animals (Realini, Williams, Pringle, & Bertrand, 2001) or video-image analysis (VIA) of carcasses (Allen & Finnery, 2001) and live animals (Sakowski, Sloniewski, & Reklewski, 2002; Hyslop et al., 2008) have been used as a means of assessing carcass characteristics at slaughter.

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More recently, the use of X-ray computed tomography (CT) in carcasses has been investigated in pigs, sheep and beef cattle. CT scanning is a non-invasive technique that can provide *in vivo* predictions of carcass composition, which are used in pig and sheep breeding programmes (Simm, Lewis, Collins, & Nieuwhof, 2001; Aass, Hallenstvedt, Dalen, Kongsro, & Vangen, 2009). Very accurate *in vivo* predictions of muscle, fat and bone weight were reported in both species (sheep: Jones, Lewis, Young, & Wolf, 2002; Lambe, Young, Mclean, Conington, & Simm, 2003; Macfarlane, Lewis, Emmans, Young, & Simm, 2006; pigs: Szabo et al., 1999). Very accurate predictions of carcass tissue weights were also reported from the CT scanning of carcasses of pigs (Dobrowolski, Romvari, Allen, Branscheid, & Horn, 2003; Vester-Christensen et al., 2009) and sheep (Johansen, Egelandsdal, Røe, Kvaal, & Aastveit, 2007; Kongsro, Røe, Aastveit, Kvaal, & Egelandsdal, 2008). In beef cattle, although the size of the CT scanner gantry prevents CT scanning of live beef cattle or whole carcasses, Navajas et al. (2010, in press) reported that it could be used as an economical and faster alternative to total dissection for determining carcass composition based on the scanning of primal cuts. This allows a non-invasive assessment of composition without affecting the value of primal cuts. More comprehensive and faster scanning is possible due to the development of CT technology, such as spiral CT scanning (SCTS), which has been recently investigated in animal and meat science. Predictions of beef and sheep carcass composition as well as muscle volume and weights and muscularity in sheep, based on *in vivo* or post-slaughter SCTS, were found to be very accurate (Navajas et al., 2006, 2007, 2010, in press). Although multivariate analysis was used to predict sheep carcass composition from CT images (i.e. Johansen et al., 2007; Kongsro, Røe, Kvaal, Aastveit, & Egelandsdal, 2009), it has not been applied for estimating beef carcass composition by SCTS.

The prediction of meat quality using CT scanning has been investigated based on the average CT muscle density, calculated as the average values of the pixels segmented as muscle in the CT images. In sheep, Karamichou, Richardson, Nute, McLean, and Bishop (2006) found strong negative genetic correlations of CT muscle density with IMF content and taste panel scores for flavour, juiciness and overall palatability; although no genetic association with tenderness was identified. Associations of variable magnitude were reported with different fatty acids (Karamichou, Richardson, Nute, Gibson, & Bishop, 2006). A more sophisticated approach was used by Lambe et al. (2009) to quantify the association between CT parameters and IMF in sheep. By fitting parameters of a mixture of four normal overlapping distributions for the full tissue density the accuracy increased by 10% compared to those using average muscle density.

Chemical and physical differences in the tissues between live animals and carcasses are expected due to the post-mortem transformation process, particularly in the case of muscle/meat (i.e. lower water content due to drip losses, differences in tissue density because of low temperatures, histological differences due to ageing, etc.) (Lawrie, 1998). CT scanning of meat may capture the changes of tissue densities and properties and therefore improve the predicting ability of CT data for both composition and quality traits compared to measurements in the live animal. In the case of beef, moderate to low phenotypic correlations were found between average CT muscle density of beef primals and IMF in a preliminary study by Navajas et al. (2009). To the best of our knowledge, there are no studies testing the use of SCTS to predict quality parameters of beef using a multivariate analysis.

The aim of this study was to investigate, using a multivariate approach, the potential of SCTS tissue density values as predictors of beef cuts composition and beef quality characteristics in crossbred Aberdeen Angus and Limousin cattle. Beef quality traits included were technological parameters, eating quality traits, fatty acid profile and intramuscular fat content.

2. Material and methods

2.1. Animals and management

This study was carried out as part of a larger trial in which a total of 88 Aberdeen Angus (AAx) and 106 Limousin (LIMx) crossbred heifers and steers were slaughtered in the autumn/winter months of 2006, 2007 and 2008. The AAx and LIMx animals had average live weights of 582 and 609 kg and average ages at slaughter of 546 and 544 days, respectively.

Within the 194 animals, 144 animals were slaughtered in 2006 and 2007 and produced within a two-breed reciprocal crossbreeding rotation using Aberdeen Angus and Limousin breeds at the SAC Beef Research Centre (BRC). The 144 animals from the SAC BRC were finished during the final 2–4 months of their production cycle on similar diets consisting of 1st cut grass silage and a barley based concentrate (50:50 on a dry matter basis) which was offered *ad libitum* as a completely mixed ration on a daily basis. The ration analysis averaged 381 g kg^{-1} dry matter (DM), 12.0 MJ kg^{-1} DM metabolisable energy and 139 g kg^{-1} DM crude protein. All animals remained on these diets for a minimum of eight weeks after which they were selected for slaughter according to standard commercial practice (target grades R4L or better). The remaining 50 animals were slaughtered in 2008, sourced from different commercial farms and sired by either Aberdeen Angus or Limousin sires but the breed of the dam was unknown. These 50 animals were selected in the commercial abattoir where all slaughtering took place on the basis of sire breed, sex and the fact that both farm of origin was known and the individual sire identity was recorded on the animal passport. Although the ration formulation was not known, their ages and slaughter dates suggest that their finishing management was likely to be similar to that of the BRC animals.

2.2. Meat samples

After slaughter, the left carcass sides were kept and chilled for 48 h, until quartering between the 10th and 11th ribs. After quartering, carcass sides were split into 20 primal cuts, as illustrated in Fig. 1. From the sirloins, two other cuts were obtained which will be referred to as 11–12th rib sirloins and 13th rib sirloin, whilst the remaining lumbar section of this cut will be referred to as lumbar sirloin. *M. longissimus thoracis et lumborum* of these cuts was chosen for assessing all the traits in the present study since most meat quality studies (e.g. Prieto, Roehe, et al., 2009; Prieto, Ross, et al., 2009) chose it for being the most homogeneous and representative muscle of the carcass. Colour was measured after 45 min blooming on the 11–12th ribs sirloin. Lumbar sirloins and 11–12th rib sirloins were vacuum packed in the abattoir and transported to the SAC-BioSS CT unit in Edinburgh, where they were CT scanned, and then sent to the University of Bristol for dissection and meat quality analysis. Cuts were kept and transported at 1–2 °C. The 13th rib sirloins were not vacuum packed as they were retained for textural slice shear force (SSF) measurements that were taken approximately 72 h after slaughter.

After dissection, samples of the *M. longissimus thoracis* of the 11–12th rib sirloins were vacuum packed and aged at 1 °C to 14 days post-mortem for assessment by a trained sensory panel. From the dissected *M. longissimus lumborum* of the sirloins, a 75 mm-long piece of the cranial end was separated, vacuum packed, aged for 10 days and used to assess instrumental texture by Volodkevitch shear jaws. From an adjacent section, 25-mm thick steaks were vacuum packed and used to determine texture by a second SSF, after an ageing period of 14 days. The next 25 mm of the lumbar sirloin was taken, vacuum packed and frozen for subsequent analysis of fatty acid composition and intramuscular fat content.