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Relationships between marbling measures across principal muscles

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ABSTRACT

As marbling is a principal input into many grading systems it is important to have an accurate and reliable measurement procedure. This paper compares three approaches to measuring marbling: trained personnel, near infrared spectroscopy (NIR) and image analysis. One 25 mm slice of meat was utilised from up to 12 cuts from 48 carcasses processed in Poland and France. Each slice was frozen to enable a consistent post-slaughter period then thawed for image analysis. The images were appraised by experienced beef graders and the sample used to determine fat content by NIR. We find that image analysis based marbling measures are capturing something different to trained personnel and that there is a strong relationship between near infrared spectroscopy and trained personnel. Finally, we demonstrate that marbling measures taken on one muscle can be predictive of marbling in other muscles in the same carcase. This is particularly important for cut based models such as the Meat Standards Australia system.

1. Introduction

Marbling is an important input into many beef quality grading systems. It is reported to affect taste (Wood et al., 2004; Calkins & Hodgen, 2007) and to have a significant relationship to consumer acceptance of beef steaks (Platter et al. (2003). If marbling level is to be recognised and encouraged in production systems or utilised as a carcase grading input it needs to be measured accurately, reported to the cattle producer and incorporated within beef classification and payment systems.

In Poland and other European Union (EU) countries beef carcases are evaluated under the EUROP classification system. This system describes carcase conformation (E, U, R, O, P) and external fatness (1–5) but does not report marbling, being focused on describing yield rather than eating quality indicators. The EUROP system is not designed to assess the quality of individual cuts of beef. In Poland, research under the ProOptiBeef project is focused on improving consumer satisfaction with the quality of beef, including consideration of implementing a quality grading system in conjunction with EUROP assessment.

Evaluation of quality grading systems has included both direct collection of data from Polish consumers and beef samples and a review of major existing grading systems, in particular those used in the United States of America (USA), Australia and Japan. In each of these systems, marbling or intramuscular fat (IMF) content is considered one of the main factors to assess beef eating quality as related to consumer satisfaction (Smith, Griffin, & Johnson, 2013; Anonymous, 2014; Anonymous, 1996). These classification systems are more complex than the EUROP system and seek to assign levels of consumer satisfaction (eating quality) in addition to yield based measures. The Japan Meat Grading Association (JMGA) system and the United States Department of Agriculture (USDA) system have independent quality and yield grades for a carcase whereas the Australian Meat Standards Australia (MSA) system only describes eating quality, but at a cut rather than carcase level.

The use of image analysis to produce the official JMGA photographic standards and in direct carcase assessment has been reported by Kuchida, Osawa, Hori, Kotaka, and Maruyama (2006) and may provide a more sophisticated and objective tool for marbling classification (Kuchida, Kurihara, Suzuki, & Miyoshi, 1997; Kuchida, Konishi, Suzuki, & Miyoshi, 1998; Kuchida et al., 2000; Kuchida, Suzuki, & Miyoshi, 2001). Konarska et al. (2013) also reported a test procedure for image analysis of beef samples that had been first frozen and then thawed prior to analysis. This procedure was developed to enable collected samples to be assessed under constant laboratory conditions without introducing significant potential bias through extended times between boning at commercial slaughterhouses and image analysis. In brief the procedure applies a constant thaw and bloom time prior to analysis. The current paper incorporates these results in assessing broader issues in relation to alternative measures and intercut relationships. Camera grading of marbling utilizing image analysis of the quartered LD is also

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allowed under USDA and is becoming more widely used (Moore et al., 2010).

In Australia the MSA beef grading system is used to predict the quality of beef in relation to consumer acceptance (Ferguson, Thompson, & Polkinghorne, 1999; Polkinghorne, Thompson, Watson, Gee, & Porter, 2008; Thompson, 2002). The MSA grade is calculated for each cut on the basis of observed or measured carcase traits at grading. Marbling is an important component of the grade calculation and assigned by graders in 10 point increments within a scale of 100 to 1190 supported by 10 digitally produced pictorial standards (Polkinghorne et al., 2008). In all three systems graders are trained to consider the marbling particle size and distribution in addition to the simple proportion of visual IMF. It is believed that fine, evenly distributed marbling relates to a more consistent and superior eating experience than meat with an equivalent total fat content but irregularly distributed or present in larger coarse particles (Smith, Tatum, Belk, & Scanga, 2005). This has important implications in considering potential objective measurement technologies; if total IMF percentage was in fact adequate then non-invasive technologies may be able to predict this from a hot or cold carcase scan. If distribution and fineness are important considerations, assessment is far more demanding and likely to require carcase ribbing and evaluation by either visual or photographic image analysis.

In each of the described systems marbling is only assessed on a single cross-section of the *M. longissimus thoracis* (LT) (JMGA) or *M. longissimus thoracis et lumborum* (LTL) (USDA and MSA) with this single assessment providing a whole of carcase estimate. In the MSA system marbling effects for individual muscles are defined in relation to the observed LTL marbling site. The marbling effect, related to the LTL observed site, and reported by Watson, Polkinghorne, and Thompson (2008) varies widely by muscle. What cannot be ascertained however is the extent to which this intermuscle variance relates to a direct effect of marbling in each muscle versus the accuracy of individual cut marbling relationships to LTL marbling. This again has important implications in regard to future grading technologies: if LTL marbling provides similar accuracy to actual individual muscle marbling then a continued focus on accurate measurement of the quartered LTL site is warranted. If not, attention to developing technology that enables individual cut marbling or IMF assessment would rate a higher priority.

The aim of this study was to determine the level of marbling for individual muscles within a range of carcases, to compare alternative marbling measurement approaches and examine correlation between the alternative measures, between individual muscles, and between the LTL assessment site and individual muscles. The study was conducted within the ProOptiBeef project which is evaluating the introduction of a beef quality grading system in Poland. Results of the study will assist in identifying the relative merits of potential marbling assessment approaches that could be incorporated in an eating quality assessment system for Polish beef and provides evidence to help inform any improvements to existing international systems.

2. Methods

2.1. Data collection

Cuts were collected from 27 Polish dairy and dairy by beef (Charolais, Belgian Blue, Limousin) crossbred entire male and female cattle aged between 14 and 24 months grown under the Project "Optimization of beef production in Poland in accordance with the strategy from the fork to the farm" (UDA-POIG.01.03.01-00-204/09-03) after slaughter at a commercial Polish slaughterhouse. Further samples were obtained from 18 female cattle, aged 31 to 178 months, at a French slaughterhouse also including dairy, predominantly Holstein, and beef (Charolais, Croisé, Gascon) breeds. Both slaughterhouses were registered for EU export production and complied with EU regulations for animal welfare, hygiene and further regulations. There were no non-standard treatments applied at any point prior to sample fabrication post-deboning.

All carcases were graded to EUROP specification prior to chilling. Immediately prior to deboning on the morning after slaughter, carcases were ribbed at the 12/13th rib and allowed to bloom for 20 min. USDA and MSA grading inputs including marbling, ossification, rib fat depth and pH were recorded.

Individual primal cuts were collected during deboning and uniquely identified. Approximately 48 h post-slaughter the primal cuts were trimmed of external fat and epimysium and separated into individual muscles. A 25 mm slice was taken across the grain of each muscle, labelled and vacuum packed.

Twelve muscles were collected in Poland and six in France. Table 1 presents the muscles collected in France and Poland used for image analysis together with the number of each and the associated cut codes, based on MSA description protocols. The codes are a combination of the abbreviation of the common primal cut name and the position of the muscle in the alphabetical list of muscle names (Anonymous, 2005).

The Polish samples were aged 21 days and the French samples for 10 days post-slaughter in vacuum packaging at 1 °C. All samples were then frozen and stored at −20 °C. The frozen samples were transported to the Warsaw University of Life Sciences.

Subsequently they were transferred to a refrigerator 24 h before photographing and thawed to 2 °C. A test procedure was adopted in which thawed samples were removed from the refrigerator, the vacuum packaging removed and the steak then placed on paper towel for 30 min to bloom (Konarska et al., 2013). Each sample was then prepared for measurement by drying the surface with paper towel and aligning in a standard position on an A4 sheet of white paper which included a mark to center the steak and the individual sample identification code.

2.2. Image analysis procedure

Each sample was photographed by a digital camera system. A NIKON D3200 camera mounted on a jig at 50 cm height with an APS-C image sensor with a minimum resolution of 15 megapixels and manual settings of ISO 400, shutter speed 1/50 and f-number 3.5. The sample was photographed within a muslim "tent" illuminated by two flash units with a capacity of minimum 200ws. Images were stored as both raw data and reduced to JPEG format. Photographing was carried out on three consecutive days. ColorCheckerPassport (X-rite) was taken for the first shot of each day and used for the colour calibration.

Image analysis was performed using the Beef Analyzer II software (Hayasaka Ricoh Co. Ltd., Sapporo, Japan). To specify muscle area a border line (line width is 1 pixel) was semiautomatically drawn and manually corrected using an image analysis program developed by Kuchida et al. (1997). Further procedures reported by Kuchida et al. (2006) were used to produce a range of marbling measures; the number of marbling particles, two fineness indexes and coarseness indexes of marbling

Table 1
Sample numbers examined by image analysis by cut and country of origin.

Muscle	Code	France	Poland	Total
M. triceps brachii caput longum	BLD096	0	27	27
M. semispinalis capitis	CHK074	0	4	4
M. serratus ventralis cervicis	CHK078	0	25	25
M. longissimus thoracis	CUB045	0	26	26
M. rectus femoris	KNU066	17	14	31
M. vastus lateralis	KNU099	0	18	18
M. biceps femoris	OUT005	16	27	43
M. infraspinatus	OYS036	0	27	27
M. gluteus medius	RMP131	11	14	25
M. longissimus lumborum	STR045	18	26	44
M. psoas major	TDR062	18	27	45
M. semimembranosus	TOP073	18	27	45
	Total	98	262	360