EVALUATION OF MARBLING AND COLOR OF FROZEN BEEF USING IMAGE ANALYSIS

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Abstract – While image analysis provides an ideal objective means to evaluate marbling and colour of beef muscles it is logistically difficult to apply during processing. This study investigated the collection of samples in the slaughterhouse which were then frozen after ageing for laboratory evaluation after thawing. 360 samples fabricated from 12 muscles collected from a diverse range of Polish and French cattle were utilised in the study. Results were encouraging with image analysis techniques providing clear marbling contrasts across cuts and carcasses and good agreement between estimates of meat colour by analysis and Minolta L*a*b* readings.

Key Words – Marbling, Color, Frozen beef

I. INTRODUCTION

Photographic image analysis offers benefits in providing objective evaluation of beef muscle marbling and colour combined with the ability to store images [14, 9].This may overcome problems in comparing manual evaluation by graders in the slaughterhouse, [12, 3, 10], particularly where trying to equate marbling levels evaluated under alternative systems such as those used in Japan, Korea, USA and Australia summarized by Polkinghorne and Thompson [8]. It may further offer the ability to evaluate individual carcass muscles rather than rely on their presumed relationship to alternative *M. longissimus dorsi* quartering sites.

However, it is difficult to achieve this in a commercial slaughterhouse environment. If small steak sized samples could be collected during deboning and frozen for later laboratory analysis many of these difficulties could be overcome. Issues to be resolved include suitable protocols for freezing, thawing, photographing and analysis of images. Developed protocols need to be tested and evaluated for effectiveness.

II. MATERIALS AND METHODS

Test material was obtained from 24 Polish dairy and dairy by beef (Charolais, Belgian Blue, Limousin) crossbred 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 cattle, aged 31 to 178 months, at a French slaughterhouse also including dairy, predominantly Holstein, and beef (Charolais, Croisé, Gascon) breeds.

All carcasses were graded to EUROP specification prior to chilling with hourly pH and temperature readings taken for five hours after chiller entry. Immediately prior to deboning on the morning after slaughter carcasses were ribbed at the 12/13th rib and allowed to bloom for 20 minutes. USDA (United States Department of Agriculture) and MSA (Meat Standards Australia) grading inputs including marbling, ossification, rib fat depth and meat colour were recorded. Individual primal cuts were collected during de-boning and individually identified. Approximately 48 hours post slaughter the primal cuts were trimmed of external fat and epimysium and separated into individual muscles. A 25mm slice was taken across the grain of each muscle, labeled and vacuum packed.

The twelve muscles collected in Poland were *M. triceps brachii caput longum* (BLD096), *M. semispinalis capitis* (CHK074), *M. serratus ventralis cervicis* (CHK078), *M. longissimus dorsi* (CUB045), *M. rectus femoris* (KNU066), *M. vastus lateralis* (KNU099), *M. biceps femoris* (OUT005), *M. infraspinatus* (OYS036), *M.gluteus medius* (RMP131), *M. longissimus dorsi et lumborum*

(STR045), *M. psoas major* (TDR062) and *M. semimembranosus* (TOP073). In France samples were prepared from *M. longissimus dorsi et lumborum* (STR045), *M. biceps femoris* (OUT005), *M. semimembranosus* (TOP073), *M. psoas major* (TDR062), *M.gluteus medius* (RMP131) and *M. rectus femoris* (KNU066).

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.

They were transferred to a refrigerator 24 hours before photographing and thawed (temperature -2 degrees 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 minutes to bloom. Each sample was then prepared for measurement by drying the surface with paper towel and standard alignment on an A4 sheet of white paper which included a mark to center the steak and the individual sample identification code.

Each sample was photographed by a digital camera system. The system utilized a NIKON D3200 camera mounted on a jig at constant height with an APS-C image sensor with a minimum resolution of 15 megapixels and settings of ISO 400, shutter speed (1/50) and f (3.5) stop set to manual settings. 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 color calibration.

The images were then analysed following a procedure developed by Kuchida et.al [5] using image analysis software to calculate marbling %, fineness index and coarseness index of marbling and estimated L* values.

After photographing an instrumental color measurement was made using a Minolta CR 400 to determine L * a * b * values following the procedures described by Tapp et.al [11]. A pH reading was also made for each sample.

III. RESULTS AND DISCUSSION

The analyzed sample images were of very high quality with marbling clearly portrayed in the JPEG format. The large range was confirmed by computerized image analysis. Table 1 presents the minimum and maximum marbling values per muscle in the French samples together with the range in the marbling fineness index. For the French beef marbling ranged from 2.2% to 23.9% with fineness index values from 0.26 to 2.56. A considerable range in values was found in all muscles with the maximum values from around 3 to 8 times the minimum. Even greater diversity was exhibited in the Polish samples ranging from 1.4% to 36.5% across the 12 muscles with fineness index from 0.16 to 2.67 as shown in Table 2.

Table 1 The level of marbling in the six muscles from the French dairy and beef cattle.

Muscle	Minimum Marbling	Maximum Marbling	Minimum Fineness Index	Maximum Fineness Index
KNU066	3,3%	15,8%	0,47	1,79
OUT005	3,4%	23,8%	0,48	2,56
RMP131	2,5%	8,2%	0,31	0,99
STR045	2,2%	18,3%	0,31	2,02
TDR062	6,5%	23,9%	0,69	2,24
TOP073	2,8%	16,5%	0,26	2,22

Table 2 The level of marbling in the 12 muscles from the Polish cattle obtained from beef and dairy breeds.

Muscle	Minimum Marbling	Maximum Marbling	Minimum Fineness Index	Maximum Fineness Index
BLD096	2,2%	11,2%	0,26	1,34
CHK074	3,6%	8,9%	0,46	0,91
CHK078	2,6%	36,5%	0,38	2,67
CUB0045	2,8%	33,2%	0,33	1,74
KNU066	2,6%	16,6%	0,34	1,51
KNU099	1,4%	16,5%	0,16	1,59
OUT005	3,4%	32,8%	0,34	2,62
OYS036	8,2%	27,8%	0,39	1,73
RMP131	2,0%	10,9%	0,23	0,88
STR045	3,3%	24,8%	0,26	1,81
TDR062	3,4%	22,5%	0,36	2,06
TOP073	2,7%	21,6%	0,28	2,35

The data also demonstrates a considerable range in marbling across major carcass muscles in two cattle populations comprising dairy, beef and dairy by beef cross breeds. Results were encouraging with image analysis techniques providing clear marbling contrasts across cuts and carcasses utilizing frozen and thawed samples. Further work to determine

repeatability and relationship to fresh samples is required.

According to a study by Tian et.al [12] and Li et.al [6] meat marbling and color can indicate beef quality. Numerous studies in recent years have driven research on chemical assessment of intramuscular fat content in different beef muscles [7, 2, 9, 13]. However, in slaughterhouses marbling score is performed by graders or computer image analysis. The study shows variation between muscles raising further questions as to the ability of the traditional *M. longissimus dorsi* assessment sites (4th/5th, 10th/11th and 12th/13th rib) to adequately estimate marbling level as such or the effect of marbling on sensory response in other carcass muscles.

The samples' pH readings ranged from 5.06 to 6.42 (mean 5.58, st.dev 0.17) consistent with an extensive range in meat colour. Minolta L* values also ranged extensively from 29.6 to 50.9 (mean 38.2, std.dev 3.5). Estimates of L*, a* and b* values were also derived from image analysis using algorithms provided by Kuchida (Patent No. JPN2012-115719). Comparison of the L* estimate demonstrated a strong relationship with the Minolta readings as illustrated in Figure 1.

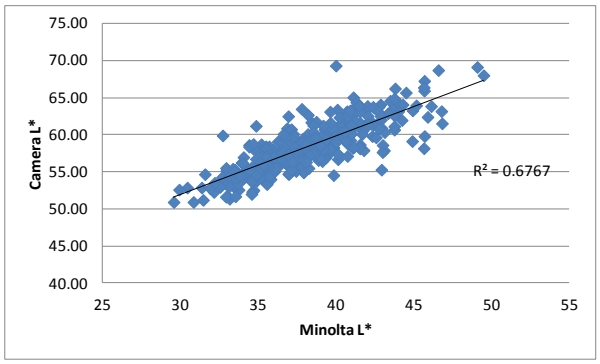

Figure 1. Relationship between camera and Minolta L*

IV. CONCLUSION

The experiment demonstrated that image analysis could be used on frozen and thawed muscle samples to evaluate wide ranges of marbling and meat colour. The extreme range of marbling found in each muscle and the apparent lack of a constant relationship between muscles in the two data sets raises questions as to the predictive value of the traditional *M. longissimus dorsi* grading sites in relation to other muscles. The results of this experiment indicate that image analysis may be used as a basis to objectively examine the marbling relationship between muscles. Further work to determine repeatability in frozen and thawed samples and to determine relationship to fresh meat is required. Stored images also provide an excellent basis from which to develop equivalence data between different grading systems and the added ability to quantify fineness and distribution. These data may also be useful in conjunction with chemical fat and fatty acid composition data to assist in prediction of consumer sensory response. The strong relationship between measured Minolta values and those predicted from the images is also encouraging. It is concluded that image analysis may also provide a useful estimate of meat colour evaluated from thawed samples after a period of ageing and frozen storage.

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