5-P10

ON-LINE MEASUREMENT OF INTRAMUSCULAR FAT/MARBLING IN BEEF CARCASSES USING ELECTRICAL IMPEDANCE

Niels T. Madsen, Claus Borggaard, Allan J. Rasmussen & Lars Bager Christensen

Danish Meat Research Institute, DK-4000 Roskilde, Denmark. e-mail: ntm@dmri.dk

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Background

Intramuscular fat (IMF) in beef carcasses is important for eating quality and palatability. Visual assessment of marbling is internationally used as an indicator of IMF. Traditionally, assessment of marbling has been a part of the classification system and is also a basis for substantial price differentiation to the farmers e.g. in Japan and the USA. In several countries marbling also has become an important feature of the official sorting systems for quality assured beef, e.g. Meat Standards Australia or the Danish Livestock and Meat Board controlled brand "Luksus" (luxury). Internationally, local butchers and meat companies have their own more or less formal criteria for marbling.

The visual assessment of marbling, however, lacks objectivity and can be applied only after ribbing the carcass which postpones the final disposal. IMF also varies considerable within the *longissimus dorsi* muscle (LD) (Zembayashi & Lunt,1995) which limits accuracy of visual scoring of a cross sectional view relative to measuring a larger volume of LD. A VIA measurement e.g. the Australian Viascan® of the rib eye is objective, but can only be applied on the cut surface. Instruments giving results about IMF in the warm carcass immediately at the end of the slaughter line should therefore have a considerable market potential.

Objective

To develop a prediction model for intramuscular fat in a beef carcass at the end of the slaughter line using invasive multifrequency electrical impedance measurement in LD.

Methods

Several methodologies have been investigated for early objective measurement of IMF. However, widespread commercial use has been limited e.g. for ultrasound, invasive visual or NIR spectroscopy and VIA. The concept of using the different electrical properties of fat and meat has been used for a long time in the meat industry e.g. the Danish KSA-meter used in the 1970es. Slanger & Marchello (1994) demonstrated off line prediction of IMF in beef samples using electrical impedance at 50 kHz. In 1997, the DMRI developed a hand held battery driven hexapolar intramuscular fat spectrum analyser, WO 99/01754 (1998). The apparatus consists of a hardware solution of six partly insulated pointed electrode poles with a diameter of 3 mm (Figure 1). The electronics makes it possible to send a constant current between the outer electrodes and to measure the impedance between the inner set of parallel electrode pairs. Impedance is measured as the ohmic resistance and an imaginary part at ten different frequencies from 50 to 50,000 Hz. Out of a total of 40 parameters from each measurement, the most relevant were chosen by multiple linear regression and subsequently used in PLS-models.

Carcasses: 185 beef carcasses were measured at two commercial beef plants, Table 1. Different categories were represented e.g. 2 young bulls, 22 steers, 23 heifers and 138 cows. App. 10 min. after carcass weighing, measurements were made in LD parallel with and perpendicular to the length of the muscle, inserting the electrodes through the fat cover aiming for the centre muscle at 1/2 lumbar (L), 13 thoracic (T) and 11/12T vertebrae, respectively. After ribbing the carcass at 5/6T vertebrae, visual marbling score was recorded using the Japanese scale (JS). Samples were excised at 1/2L vertebrae, vacuum packed and stored at 4°C for app. 7 days. Then JS scores were recorded on steaks by a sensoric panel. All subcutaneous fat was trimmed off and after comminution, a Soxtec chemical fat analysis was made.

Results and discussion

It can be difficult to differentiate between IMF and connective tissue when only visual appraisal is made. The correlation (r) (Table 1) between analytical IMF and JS scores at 1/2L is very high, indicating that IMF can be used as an objective measure for visible marbling. The JS scores at 5/6T were difficult to record under the given conditions, however, previous studies support a lower correlation to IMF at 1/2L. In Table 2, the lowest standard error of prediction (SEP) is achieved when measuring at 13T, but the differences to results from the other positions were small. Using all three measurements, it is possible to predict IMF quite accurately with a SEP of 1.39%, see Figure 2. Better results with more measurements indicate, that the IMF heterogeneity to some extent can be compensated for with more measurements. I.e. more electrodes and multiple measurements between all the individual electrodes should result in both a higher precision and potentially also in information about the spatial distribution of the marbling flecks. Both perpendicular and parallel measuring fields relative to LD length were used. In Table 2, only results for the perpendicular measurements are given, as the results from all the parallel measurements reached a correlation level around 0.5 only. The reason for a perpendicular measuring field to be better may be that the orientation and oblong shape of the marbling/IMF flecks appear as larger objects in a perpendicular rather than parallel measuring field. The prediction results are obtained using impedance only. Parameters such as category, carcass weight or EUROP classification did not improve the accuracy.

Table 1. Carcass and analysis data, n=185

	Mean	Std.dev (SD)	Min.	Max.	r to IMF*
Carcass weight, kg	279.1	65	128	413	-
EUROP-conformation, n=184	4.5	1.7	1	9	-
EUROP-fatness, n=184	3.2	0.8	1	5	0.27**
Marbling at 5/6 T, Japanese-scale n=177	3.3	1.3	1	6	0.72***
Marbling at 1/2 L, Japanese-scale	3.8	1.3	1	9	0.89***
% Intramuscular fat	4.4	2.5	1	17	-

*Significance level: p<=0.005**, p<=0.001***

Table 2. Measuring accuracy, n=185

Measurement[1]	SEP	r	SEP/ Std. dev.
1/2 L	1.85	0.70	0.74
13 T	1.71	0.75	0.69
11/12 T	1.97	0.76	0.79
All	1.39	0.83	0.56

[1]Perpendicular to LD-length

In commercial use, an instrument will often be evaluated in less mathematical terms. A meat plant operator may desire to use the instrument to select carcasses above a certain IMF threshold to ensure good eating quality. In that case, it is important to know how many carcasses he would select with too low IMF due to the measuring inaccuracy. In these data, a minimum threshold of 3.5% IMF and a selection according to the predicted IMF would result in 80.2% above and 19.8% below the threshold value as determined by chemical analysis. Such results naturally depend to a large extent on the threshold level and on the biological distribution of IMF. In another data set of 597 cows, a simulation analysis with similar prediction accuracy as above would result in 6.5% selected below the threshold. To gain even better results, a higher threshold level than the required may be applied.The results presented here show a more moderate precision when compared to results from e.g. Slanger & Marchello (1994) - IMF r^2=0.83, Gerrard *et al* (1996) - marbling, r^2=0.84. In contrast to these experiments, however, on-line commercial conditions were used by us. The total number of carcasses is higher, and the proportion of dairy cows with larger variation in age and nutritional status is dominating. From photos of the samples, the marbling heterogeneity appears to be considerable. It is not possible to indicate how a VIA system would have performed in this experiment, but this may be tested in the future. The presented measuring concept, using invasive electrical impedance, has the obvious advantage that a very early result can be obtained. It is an invasive method, but the pointed relative thin electrodes do not damage the tissue in a way that is detectable after roasting. Heterogeneous distribution of IMF in LD implies natural limits to measuring accuracy for IMF with most measuring concepts relevant for commercial application. Therefore, a trade off applies between accuracy, measuring time and cost. Depending on the market interest and production volume, it should be possible to sell this equipment at a price the meat industry would find acceptable. Prior to marketing, however, a prototype development phase will take place.

Conclusion

IMF in beef carcass LD can be predicted at the end of the slaughter line using multifrequency electrical impedance. Measuring accuracy in terms of correlation of app. 0.8 and SEP of 1.4% can be expected in a population of mainly cows with a IMF standard deviation of app. 2.5%. A perpendicular measuring field in relation to LD length is recommended.

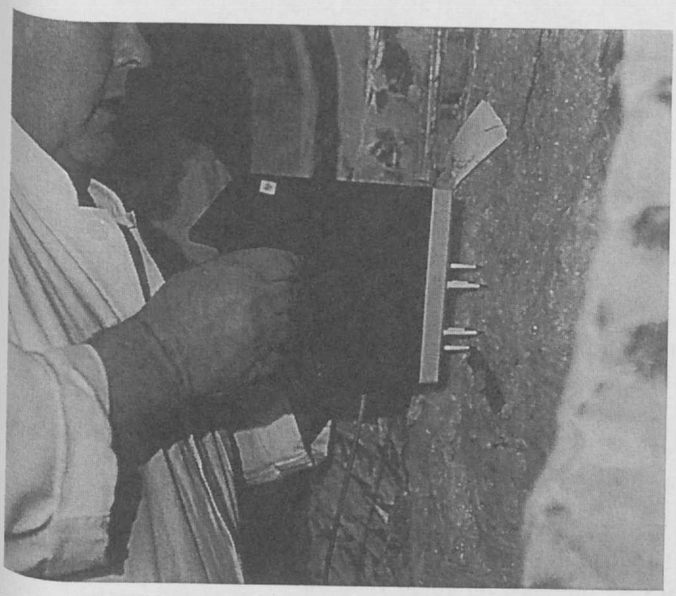

Figure 1. Hand held instrument for IMF prediction by electrical impedance

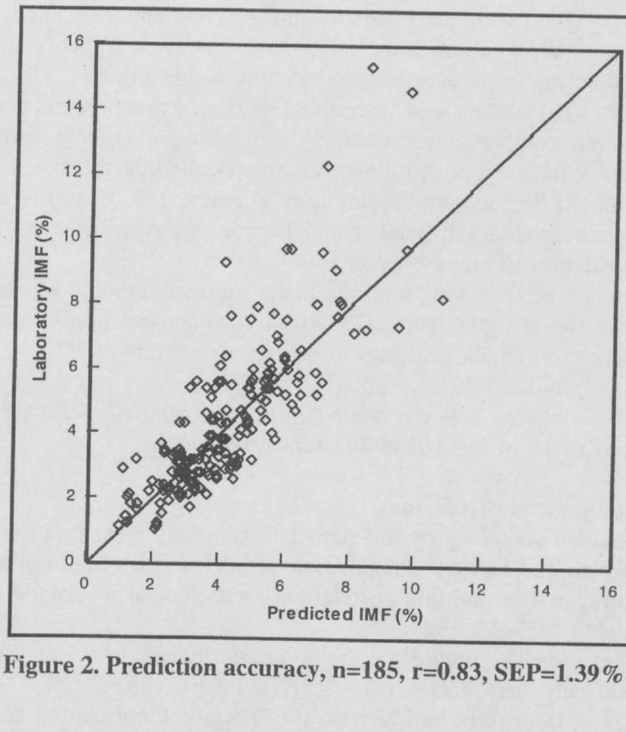

Figure 2. Prediction accuracy, n=185, r=0.83, SEP=1.39%

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