A novel method for quantitative fat analysis in meat by in vivo Magnetic Resonance Imaging

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Background

Intra muscular fat content of meat influences some important meat quality parameters, such as palatability and overall acceptance of whole meat products (Fernadez et al., 1999a; 1999b). These facts, in addition to the debate of the effect of animal fat on human health, demand accurate methods measuring fat content. Today, there are several methods to analyse fat content in meat. However, most of them are not satisfactory enough in terms of fat quantification in a cross section of a consumer size meat slice, without a use of large amounts of organic solvents or because of being invasive.

Objectives

The objective of the present study was to develop a new non destructive and non invasive technique for fat analysis in meat, that is in vivo magnetic resonance imaging (MRI) and to compare it with chemical analysis and digital photography.

Materials and Methods

8 heifers were slaughtered and cut in a commercial slaughterhouse. The fat content of *M. Longissimus dorsi* (LD) was analysed with chemical analysis (Soxlet method, AOAC 1980), MRI and by digital photography (Sony DSC –D700). Cemical analysis was carried out on piece A (Figure 1) after grinding. In vivo MRI was acquired on a Bruker Biospec wide bore horizontal magnet at 2.35 Tesla. MSME (Multi Slice Multi Echo) was applied with a volume of interest of 10 cm^3 on piece B (Figure 1). Digital photography was carried out on both sides of piece A. Image analysis software was specially developed for the interpretation of the MRI and the digital photographs. Images were computer analysed by segmentation with regard to fat, muscle and connective tissue content. In particular, segmentation algorithms (i.e. classification of different substances) have been optimised for these kinds of images. The procedure used for the NMR images was background suppression (histogram thresholding), non uniformity removing (Laplacian of Gaussian filtering), and fat extraction (convolved image thresholding). Segmentation results are shown in Figure 2.
In the case of camera colour photographs an automatic method was developed. The method was optimised to take full advantage of the information in colour images, in order to obtain a proper classification. Segmentation of muscle from fat was achieved based on their characteristics in the three-dimensional colour space (RGB), and on the intrinsic fuzzy nature of these structures, where pixels could belong to multiple classes with varying degrees of certainty. The method was fully automatic and combines a fuzzy clustering algorithm, the fuzzy c-means algorithm (FCM), with a genetic algorithm (GA), that is an optimisation technique inspired by natural evolution.

Results and discussion

The chemical analysis showed a fat content of 3.85 ±1.48 % (mean ± SD). The digital photographs showed the fat distribution on the surface with 0.13 mm resolution reflecting the distribution of fat in the meat. With only visual appraisal it is regarded as difficult to separate intra muscular fat from the connective tissue. This was also the case in the digital photographs were the fat and the connective tissue had the same colour. However, MR images provided the three dimensional structure of the samples with a clear contrast distinction between fat, connective tissue and muscle based on the chemical information of the proton mobility and distribution in the sample. The percentage of fat extracted by image analysis from MR and digital photography was compared to chemical analysis. A good correlation ($r=0.77$, $p=0.02$) was obtained between the mean fat content measured by chemical analysis and MRI. However, this result was strongly influenced by an outlier. After removal of the outlier the correlation coefficient was increased to $r=0.90$ ($p=0.01$) with a RSD of 0.65 %. Earlier results on piglets have showed a significant correlation ($r=0.64$) between in vivo (NMR spectroscopy) and in vitro (Soxlet method) measurements (Geers et.al, 1995). The lower correlation coefficient compared to our study might be explained by the lower intra muscular fat content (1.1- 2.7 %), indicating difficulties measuring lower levels of intra muscular fat in meat with NMR. The correlation between chemical analysis and the two individual digital photographs was not significant ($r=0.58$, $p=0.13$; $r=0.48$, $p=0,23$) indicating that intra muscular fat content is not readily measured with digital photography.

Conclusion

MRI allows quantification of intra muscular fat content, as well as discrimination between fat and connective tissue. This technique might be a powerful tool in measuring fat content non destructively and non invasively. Also, it is helpful in the study of the 3 dimensional variation of fat distribution . We suggest this technique to be of large potential in meat science in general.

References

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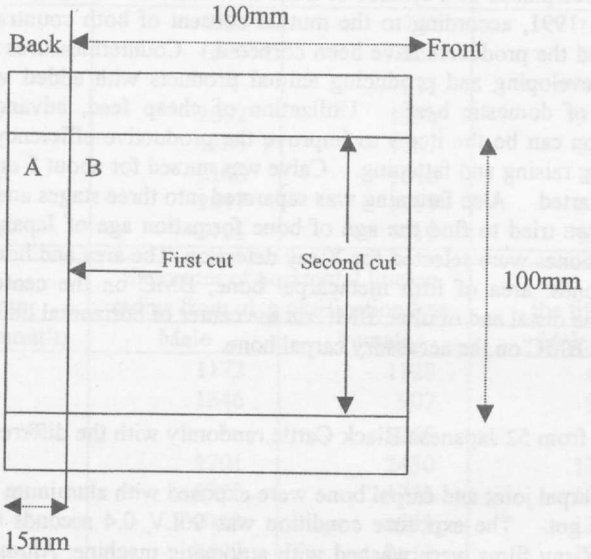

Figure 1. Sampling of meat for chemical analysis, digital photography and MR imaging.

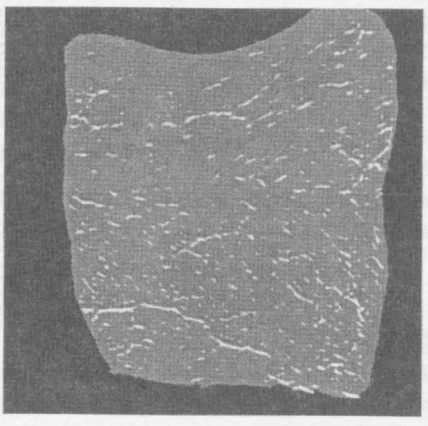

Figure 2. MR image at 2.35 tesla of meat sample. Image is 512x512 pixel matrices with 256 grey levels per pixel with resolution of 0.2x0.2 mm. Slice is 2mm thick. Fat is significantly brighter than muscle. Image obtained by Laplacian of Gaussian filter followed by thresholding.