Image analysis for the food industry: Digital color camera photographs and nuclear magnetic resonance images

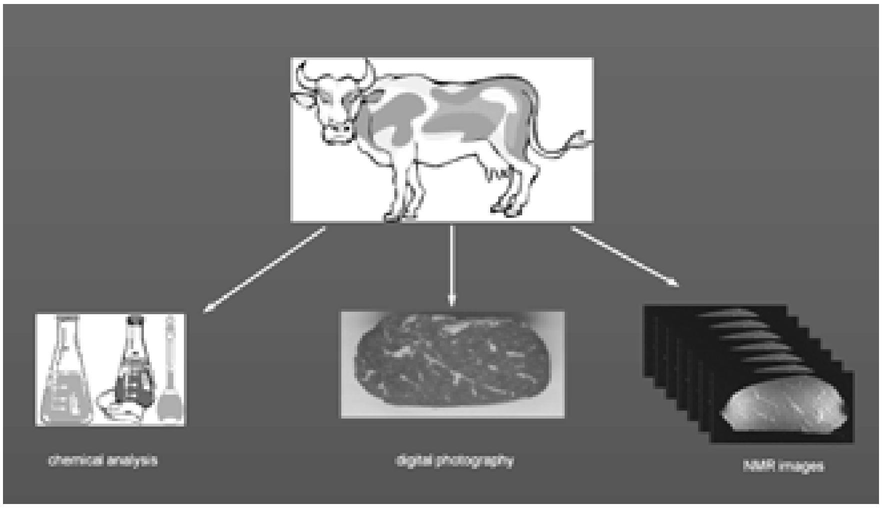

Figure 1. Methods to analyze fat content in meat.

Meat consumers expectations of quality are constantly growing. This is forcing the adoption of increasingly strict quality control measures and, as a result, the meat industry is looking for new methods of meat quality evaluation. In addition, researchers want improved techniques to deepen their understanding of meat "features". Fat content in meat is one element that influences some important meat quality parameters and has been shown to influence palatability characteristics. Though there are several ways of analyzing quantitative fat content and its visual appearance in meat, few of them are fully adequate. For instance, chemical analysis is currently used to determine intramuscular fat content in beef, but it requires large amounts of organic solvents.

Recent advances in the area of computer and video processing have created new ways to monitor quality in the food industry. (An overview of these methods is shown in Figure 1.) Image processing methods have been successfully applied to meat images in order to determine the percentage and the distribution of various substances. Specifically, we have been working with camera photographs and magnetic resonance images of meat. Segmentation algorithms have been optimized for these kinds of images in order to classify different substances as muscle, fat and connective tissue.

Color images of beef M. longissimus dorsi were captured by a Sony DCS-D700 camera. The same exposure and focal distance were used for all images. The meat pieces were lit with two lamps, each with two fluorescent tubes (15W). Polaroid filters were used on the lamps and on the camera to avoid specular reflections. Images were 1344×1024 pixel matrices with a resolution of 0.13×0.13mm. All these images were analyzed for fat percentage and distribution. In order to measure fat percentage a segmentation algorithm has been optimized for these kinds of images.[1] The method is based on the substance characteristics in the three-dimensional color space (RBG) and on the intrinsic fuzzy nature of these structures, where pixels could belong to multiple classes with varying degrees of certainty. The method is fully automatic and combines a fuzzy clustering algorithm, the fuzzy c-means algorithm, and a genetic algorithm (an optimization technique inspired by natural evolution). The percentage of various substances within the sample are determined; the number, size distribution, and spatial distribution of the extracted fat "spots" (that are impossible to measure by chemical analysis) are measured by image analysis with high accuracy.[1] Our results show that image analysis is a powerful method of quantifing the visual appearance of fat in meat.

We also investigate the use of a new technology to control the quality of food: nuclear magnetic resonance (NMR) imaging. The NMR technique has been developed and greatly improved for medical imaging and is in common clinical use. We believe that NMR imaging has a future application in the field of food science, which—in combination with image processing techniques—can lead to automatic and quantitative methods of assessing meat quality. The inherent advantages of NMR images are many. Chief among these are unprecedented contrasts between the various structures present in meat: muscle, fat, and connective tissue. In particular, connective tissue and fat, which are almost indistinguishable in color images taken by a camera, contrast highly in NMR images, i.e. fat areas are lighter, while connective tissue is darker than other structures. In addition, NMR imaging allows a 3D analysis of the meat composition, so the volumetric content of fat—not just the fat that is superficially visible—can be readily measured.

The segmentation algorithms used for Magnetic Resonance images also include a filtering technique to remove intensity inhomogeneities caused by non-uniformities in the magnetic fields during acquisition. A good correlation (r=0.77, p=0.02) was obtained between the mean fat content (measured by chemical analysis) and by the present method. This value was better than the correlation value we obtained between chemical analysis and image analysis applied to digital photographs of the same meat samples, probably because NMR imaging provided the three dimensional structure of the meat samples based on the chemical information of the proton mobility and distribution.[2] We also developed a method of describing and quantifing the distribution of fat, and we have applied it to both camera pictures and NMR images.[3] The NMR technique has proved to be a powerful tool in measuring fat content non-destructively, non-invasively and continuously.

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References

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