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Near-Infrared Light Transmission in Beef Meat and Qualitative Marbling Evaluation Using Image Analysis

Adel ZIADI[1], Xavier MALDAGUE[1] and Linda SAUCIER[2]
[1]*University Laval Québec (Qc), G1K 7P4, Canada.*
Electrical and Computing Engineering Department
[2]*University Laval Québec (Qc), G1K 7P4, Canada.*
Animal Science Department
adel.ziadi.1@ulaval.ca
xavier.maldag@gel.ulaval.ca
linda.saucier@fsaa.ulaval.ca
http://vision.gel.ulaval.ca/en/index.php

Abstract
Marbling (intramuscular fat tissue) in beef meat is one of the most important criteria for quality, notably juiciness, in meat grading systems. Visual inspection of the meat surface is the common way to assign quality grading level, which is accomplished by authorized experts called graders. In the last years, several works were proposed in order to introduce computer vision on meat quality evaluation. In these works, meat grading was based exclusively on the analysis of meat surface images. In this paper, a new technique using near-infrared light in transmission mode is used to evaluate the beef meat quality based on the marbling detection. It is demonstrated that using near-infrared light in transmission mode, it is possible to detect the fat not only on the surface, as in traditional methods, but also under the surface. Also, in combining the analysis of the two sides of the meat simple, it is possible to estimate the volumetric marbling. We compared results from traditional techniques and those provided by the near-infrared camera using light transmission. The result of this new study showed that using near-infrared light in transmission mode is a valuable technique to evaluate meat quality, thereby demonstrating the possibility of implementing this approach in a vision system.

Keywords: *Marbling, Near-infrared, Image analysis.*

1. Introduction
Meat quality is an essential factor for the Canadian cattle industry to better satisfy the consumers. In this context, marbling is one of the most important criteria for meat quality evaluation in the Canadian grading system [1]. To achieve this task, visual inspection and various probing systems are used to assign grade quality labels. It is accomplished by authorized experts referred to as graders. In the last years, computer vision was used as an alternative solution to subjectively evaluate the quality of meat. Hence, many approaches were proposed in this way: F. Yoshikawa et al. [2] presented an automatic grading system for beef marbling based on image segmentation. In this work, the authors evaluate the marbling in terms of content of fat and distribution of fat particles. An algorithm of image segmentation was proposed to segment the gray image of meat into lean and fat regions. In [3], Kazuhiko et al. developed a method to determine meat quality using the distribution of fat density in the rib-eye region. In this case, fat is identified by gray image segmentation. More recently, another approach using different light bands, especially in the near infrared (NIR) was proposed [4]-[6]. The interesting results of these lasts works were to combine the information obtained from each light band. The common conclusion of these works is the following: compared to traditional vision, the light reflected from the meat sample in the NIR band contains information about biochemical properties of the meat. Hence, the same pixel observed in the visible domain of the light spectrum provides much more or different details in the NIR domain. Naganathan et al. in [7] suggested the use of hyperspectral imaging to predict beef meat tenderness. In this work, the authors used different wavelengths (400 – 1000 nm) to analyse the images. Qiao et al. in [8], developed a new method using artificial neural network to evaluate meat pork quality: hyperspectral imaging was developed to classify meat in four categories (RFN, PFN, PSE and RSE) based on color and texture of the meat. Faucitano et al. [9], applied computer image analysis to

measure pork marbling characteristics. In [10], a system using NIR spectral reflectance to predict beef tenderness was proposed. In this work, a spectrometer was used to collect light in visible and NIR regions (400 to 2500 nm). There is no image processing in this report, but the results were interpreted by statistics from the data collected from the spectrometer.

Those previous reports demonstrated that using NIR light to analyze the meat is an interesting way to better characterize some properties of meat and its quality. On the other hand, no scientific literature was found concerning the use of NIR light in transmission mode for the evaluation of meat quality.

This paper is organized in three sections: section 2 describes the mechanism of NIR light transmission through the meat and the system of image acquisition. In section 3, experiments and results of visible and NIR images are presented. Finally, the conclusion is provided in section 4.

2. Materials and methods

In the electromagnetic radiation spectrum, near-infrared light ranges from approximately 720 to 2500 nm. It is the closest wavelength to visible light, as shown in Figure 1.

Figure 1. Electromagnetic light spectrum.

NIR light is quite an interesting mean of measuring multiple components in agriculture, foods, pharmaceuticals, textile to name only a few. In meat, it is suitable for measuring moisture and fat. NIR can penetrate through the muscle or between the fat particles because the NIR light is reflected by the marbling. Figure 2 shows the spectral profile of the pixels of lean and fat regions of a beef sample. [7]. Hence, NIR light is transmitted through the meat by a transflectance mechanism; which is a combination of reflectance and transmission, as illustrated in Figure 3. It shows clearly that the NIR light is reflected or deviated by the fat particles through the meat sample to eventually reach the opposite side.

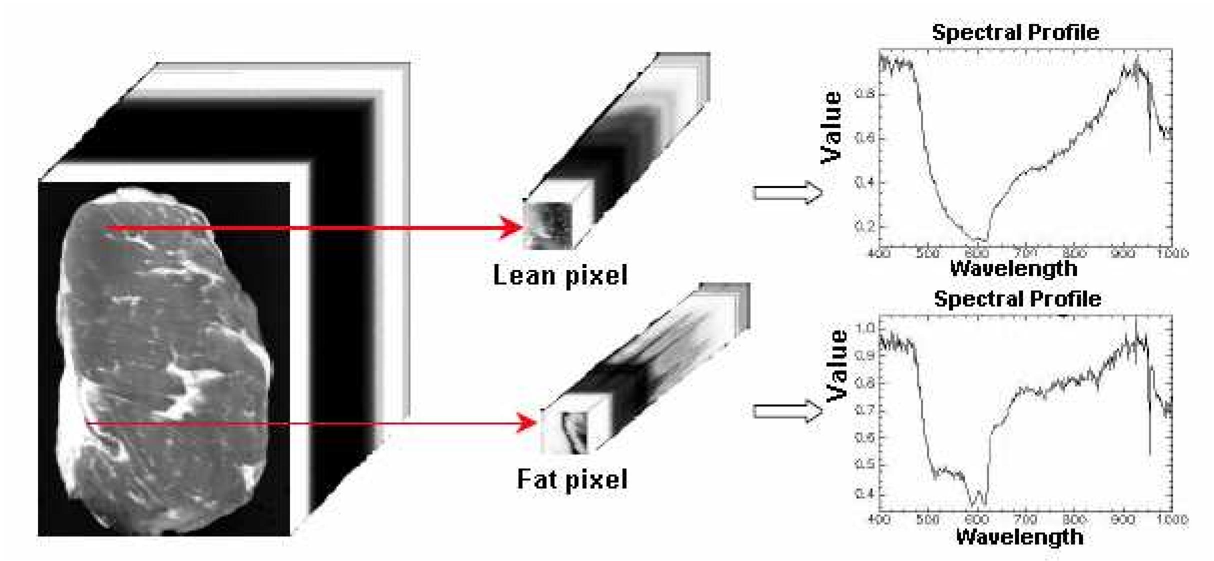


Figure 2. Spectral profile of lean and fat pixels of a beef sample.

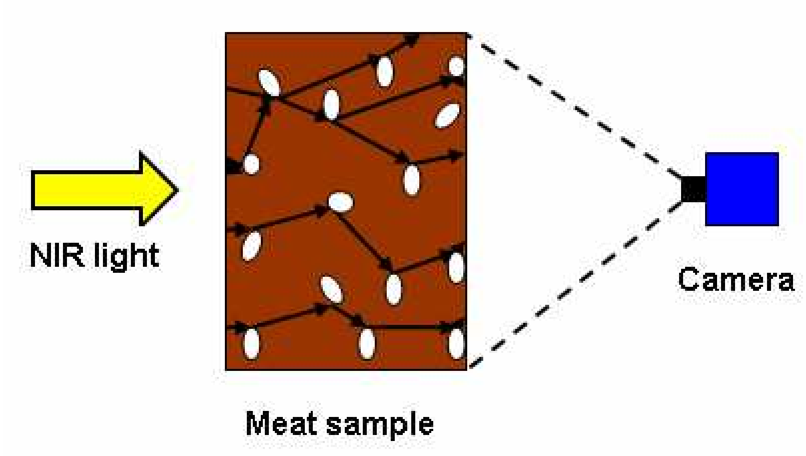


Figure 3. Schematic NIR light transflectance mechanism through the meat.

The goal of this work is to demonstrate the potential application of NIR light in transmission mode to evaluate the marbling in beef meat.

To achieve this goal, the experimental system is composed of a USB Digital Camera Phoenix, two NIR light led projectors (850 nm, 720 mw and 940 nm, 1280 mw) and a computer for the acquisition of the images. The experimented setup is the same as the schematic shown in Figure 3.

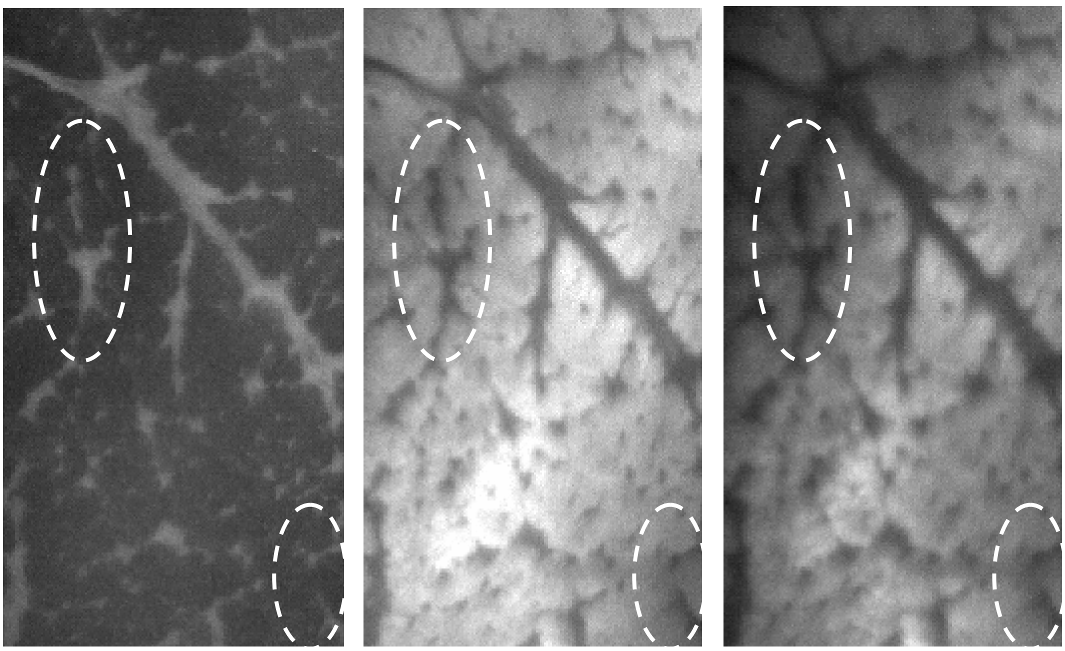
3. Results and discussion

In all of the experiments and in both domain (visible and NIR), the same camera was used. To conserve the image resolution, the same material setup was conserved for all the acquisitions in visible and NIR analysis. Only the illumination conditions were changed. For the visible light, the illumination was realized with fluorescent lamp as those used for room lighting. However, for the NIR acquisition, the fluorescent lamp was shut off and a NIR illumination was used as shown in Figure 3.

To carry out the two different experiments, i.e., ‘’visible and NIR’’, with the same camera, the filter of the camera was removed in the case of the NIR. In this way, the camera could be used for both acquisitions.

In this paper three experiments are presented. The first was conducted in the visible domain while the other two were carried out with NIR light at 850 and at 940 nm, respectively. The sample of the beef meat was obtained from a local grocery store. Its thickness was about 10 mm.

The acquisition results are presented in Figure 4.



(a) (b) (c)

Figure 4. Marbling detection images in a beef meat sample.

(a) visible, (b) NIR at 850 nm, (c) NIR at 940 nm.

The visual inspection of Figure 4 allows the observation of the following points:

* All of the marbling in the surface of the sample of meat is clearly observed in all of the image acquisitions: in both visible and NIR light. The lean meat tissue is more transparent to the NIR light than marbling, which confirms the interpretation of the NIR light transmission through the meat as presented in the introduction.

* The NIR image shows more details than the visible image. For example, in the identified areas with circles, the marbling under the surface in NIR images was detected which is not possible with visible image.

* By comparing the two NIR images, one notes that the contrast and the degree of appearance of marbling in image (c) are better than in image (b).

* NIR images were affected by the highlight. This problem is caused by two parameters: first, the meat thickness is not constant everywhere; and second, the amount of marbling distribution is not the same everywhere in the sample.

* The histograms functions of intensity pixels in images (a), (b) and (c) are presented in the following figure.

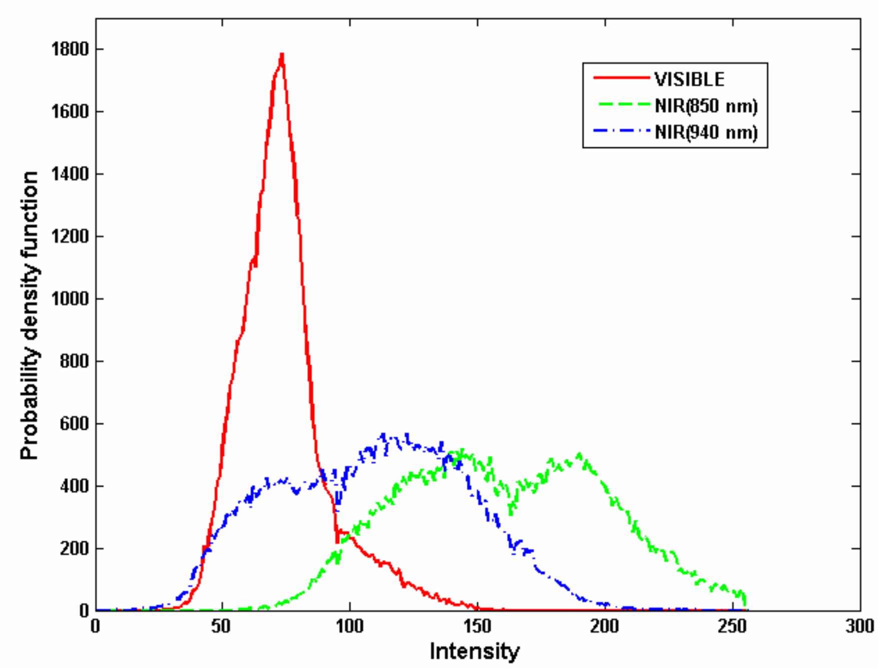


Figure 5. Histograms functions of the intensity pixels of the three images of Figure 4.

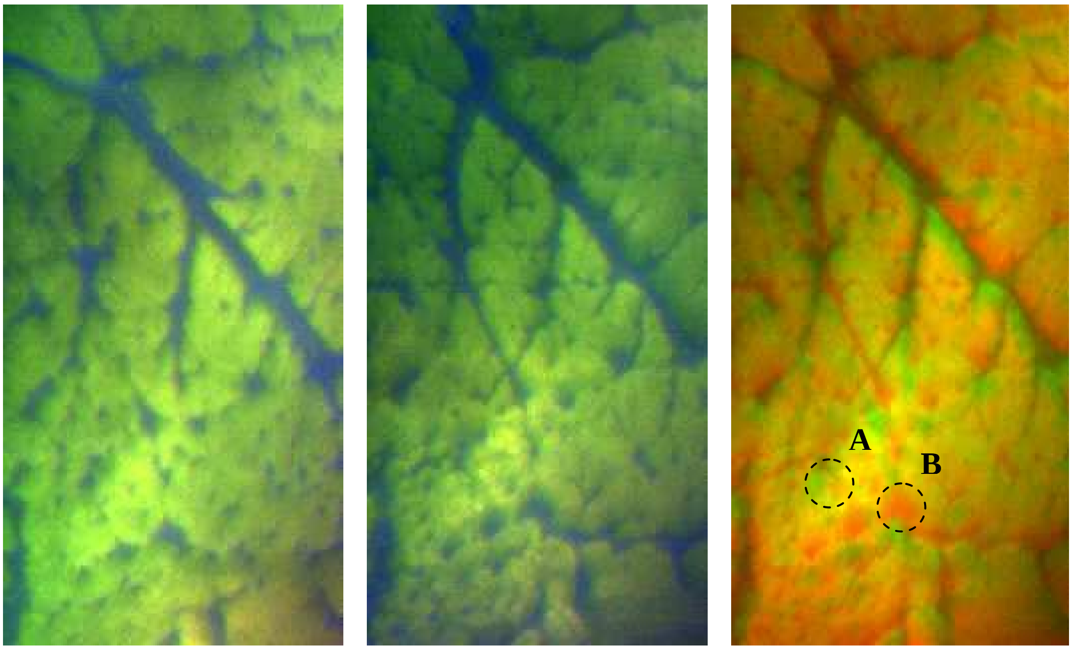
* Figure 5 shows many particularities between the three curves, in particular:

- the spectrum of intensity variation of the pixels for NIR images is larger than the other spectrum of the visible image. This shows that the content of information in NIR images is more important than in the visible image;

- in both spectra of NIR images we can see a valley that divides the spectrum in two parts (clearer = muscle and darker = marbling, respectively). In the NIR image at 850 nm, the amplitudes of the two parts are similar but for the NIR image at 940 nm, there is an important contrast between the two parts. This demonstrates that using a 940 nm light, as opposed to a 850 nm light, facilitates the detection of marbling.

- the NIR image is more nosed than visible image, this problem is caused by the camera.

These experiences demonstrate that in comparison to the meat surface image observed in the visible domain, NIR images show more details of the meat composition as shown in Figure 4. The combined representation of the three images of Figure 4 gives a color image representation of the meat side. This representation is obtained similarly to RGB color space representation by superposition of the three images considering that one image per band. Figure 6 shows the colors images of both sides of the meat simple.



(a) (b) (c)

Figure 6. NIR images of side and opposite side of the beef meat sample.
(a) side; (b) opposite side; (c) both sides.
A: color of side (a); B: color of side (b).

Figure 6 shows that color images illustrated simultaneously contain all information of the three images. Also, combining the representation of the two sides of the meat simple (Figure 6, c), it therefore becomes possible to make a relationship between both sides. This allows the estimation of the volumetric marbling. Hence, with visible and NIR images, it is possible to detect the marbling on and under the surface of the meat sample (Figure 4, Figure 6, a & b). Combining the analysis of the NIR images, side and opposite side of the beef meat sample, we can estimate the volumetric marbling of meat sample (Figure 6, c).

In this section a comparison between two different methods for the detection of marbling characteristics is presented. It has been shown that visible light images can detect marbling but are mostly limited to the surface. On the other hand, by using a system of NIR images as presented in Figure 3, it is possible to extend the marbling detection under the surface. However, NIR image processing applied to marbling detection is very difficult due to the low contrast of the marbling and the diffusion effect of NIR light through the meat (transmittance mechanism, Figure 3). Hence, combining both visible and NIR images improves the marbling estimation. Also, by combining the analysis of the two sides of the meat sample we can estimate the volumetric marbling.

4. Conclusion

In this paper, a new technique to evaluate the marbling in beef meat is presented. It is demonstrated that using NIR light in transmission mode can show the marbling under the surface which cannot be detected by visual methods proposed in computer vision. This study demonstrates that this technique is more precise and more thorough to evaluate the marbling in meat than visual methods and allows the estimation of the volumetric marbling. This is important for many applications, like meat quality and genetic selection. Furthermore, the proposed technique provides more details about marbling and information about biochemical properties of beef meat.

Since it is difficult to identify marbling using image processing in the NIR domain due to the low contrast and the highlight, it is interesting to combine visible or image of meat surface and NIR images for this process.

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