Multispectral Experimentations for Turkey Meat Quality Analysis during Storage

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Abstract

Multispectral experimentations were carried out to investigate the feasibility of determining the storage time of turkey meat. The behavior of turkey breast samples during storage was examined by spectroradiometry, spectrocolorimetry and multispectral imaging. Spectral analysis between 400nm and 700nm revealed that intensity variations on several spectral bands were related with structural and chemical changes during storage process.

Introduction

Consumers are more attentive to meat quality, so industrials and producers would like to develop techniques and define parameters for meat quality evaluation and control.

The objectives are various: product classification, defect detection,[1] quality parameters optimization (tenderness,[2,3] cooking[4]), freshness,[5] color[6]), cutting process automation, component detection and identification, food diet impact. Among the various aspects that contribute to defining the quality of meat, freshness is some of the most important. Chemical and physical transformations occur during storage like myoglobin transformation. These changes are reflected through color, tenderness, flavor, and juiciness of the meats. Different techniques have been tested to study these modifications.[7,8]

The present work was undertaken to investigate the suitability of multispectral analysis as a tool to estimate the freshness of turkey breast. Multispectral analysis was carried out by different methods: spectroradiometry, spectrocolorimetry and multispectral imaging. Spectral data were analyzed in order to extract the spectral bands for freshness determination.

Spectrocolorimetric Analysis

All skinless and boneless turkey breasts from different labels were obtained from a local supermarket. Each meat sample was analyzed on different areas. After each measurement, the slices are packaged into polyethylene bags which were placed in a plastic cooler placed in a 0°C cold room and dark environment until the next measurement were taken. The data were collected during 10 days and analyzed according to storage time.

Spectral response of turkey samples between 400nm and 700nm at 10nm interval, were recorded with a spectrocolorimeter (DataColor Microflash 200d). On each of 10 turkey breast, four areas were defined (figure 1).

Firstly, in order to characterize the spatial homogeneity response of a sample, the spectral variations of spectrocolorimetric response of different areas form a same sample and at the same storage time were measured. The figure 2 represents these results for one sample.

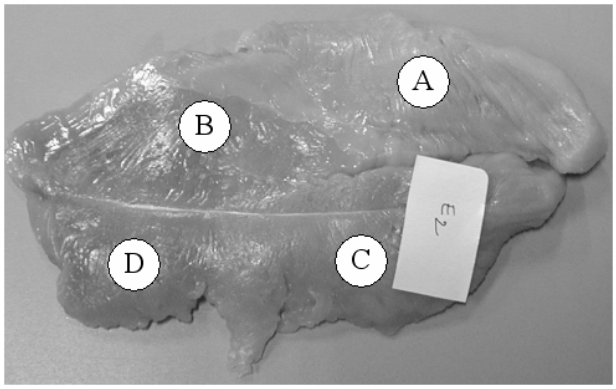

Figure 1. Example of turkey breast sample areas

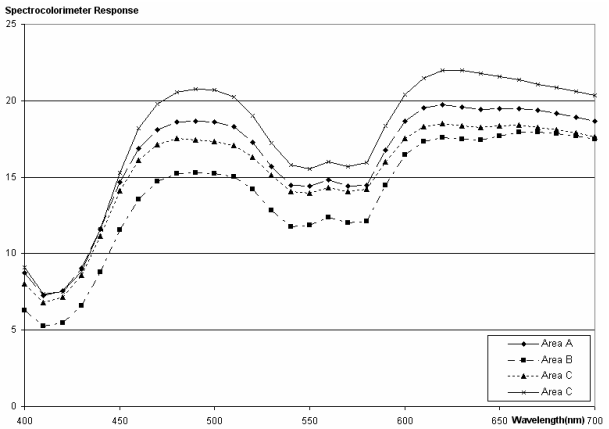

Figure 2. Spectral variations of spectrocolorimetric responses for different areas of a same sample at the same storage time

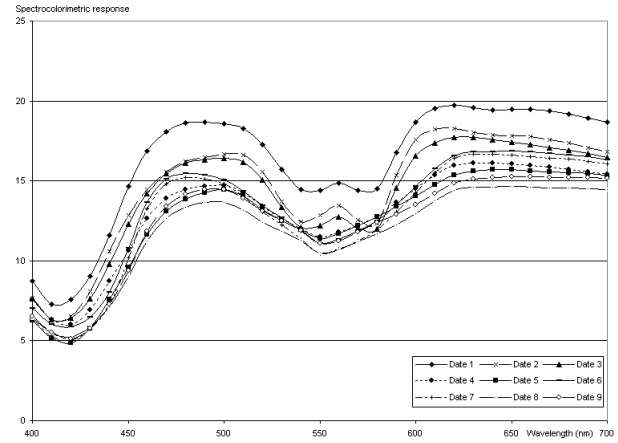

Figure 3. Spectral variations of spectrocolorimetric responses for different storage time

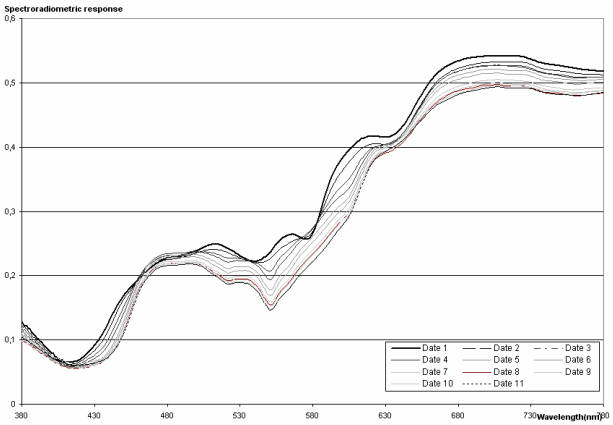

Figure 4. Spectral variations observed by spectroradiometry

Resulting spectral response amplitudes vary between different areas on a same sample. However, the shape of spectral variations of the different areas all looks alike. So spectral repartition variations in function of storage time were analyzed for each same sample area. The figure 3 represents the spectral variations of collected spectro-colorimetric responses at different storage time. Date 1 corresponds to the initial freshness state of a turkey breast.

The analysis of spectral distribution according to storage time revealed that spectral repartitions are modified with storage time: a local maximum at 560nm exists for short storage time, whereas a local minimum at 550nm decreases with the storage process. Moreover, responses amplitude variations of a same sample are not linear with storage time, spectra intersect themselves. These variations can be explained by reproductibility measurements problems, notably to measure exactly the same sample area.

These spectrocolorimetric experimentations have demonstrated variations of breast sample spectral responses in function of storage time, especially in 500nm – 600nm spectral bands. In order to define precisely these variations, their reproducibility and detectability, experimentations by spectroradiometry and multispectral imagery were carried out.

Spectroradiometric Analysis

Spectroradiometric measurements were carried out with a spectroradiometer (DataColor Microflash 200d, CS-S1W model). All reflectance spectra were collected between 380nm and 780nm with a resolution of 1nm. Several areas on a same turkey breast were analyzed in function of storage time. Spectroradiometric measurements depend on illumination conditions, so data were normalized with respect to reference white.

Firstly, variations between areas of the same turkey breast and variations between different turkey breasts at the same freshness stage were studied. Data results show that spectral response amplitudes depend on area and turkey sample but general shape of spectral distributions are similar.

The second measurement test was undertaken to analyze spectral response variations on a same turkey breast in function of storage time in order to extract freshness evaluation parameters. The figure 4 presents the variations of spectral distribution in storage time for a turkey breast area. Date 1 corresponds to the initial freshness state of a turkey breast.

With increase of storage time, some variations are observed: the general amplitude between 500nm and 600nm decreases, the response amplitude of 440nm, 525nm, 550nm, 600nm decrease with creation of a local minimum at 550nm, and loss of local maxima at 515nm and 565nm and loss of local minima at 540nm and 580nm. Moreover, response amplitudes at 410nm, 460nm, 500nm, 540nm, 573nm, 585nm are equivalent for short storage time. Besides, whereas response amplitudes are overall decreasing according to storage time, an increase of response amplitudes is observable for spectral bands between 460m and 500nm and between 573nm and 585nm, for short storage time. Unlike for long storage time, response amplitudes variations are slight around 630nm, producing a slowdown in graphic curves.

Recorded spectral responses are related to physical and chemical modifications in meat during storage. Reflection and absorption coefficient of meat vary with creation and transformation of chemical components like myoglobin pigments: OxyMyoglobin, MetMoglobin, SulfMyoglobin. For example, local maximum disappearance at 560nm can be explained by the decrease of a pigment rate having important reflectivity at this wavelength. In the same way, signal amplitude decrease at 550nm with increasing storage time can be explained by appearance (or rate increase) of a meat consituent having an important absorption coefficient at this spectral band.

Spectral distribution evolution in function of storage time allows to underline relevant spectral bands to estimate sample freshness. These spectral bands correspond to intervals where temporal variations are important but also where variations are slight or non-existent to a reference use. So to define these spectral bands, temporal variations of spectral responses have been studied and their variance characterized. However, reflectance measurements are affected by muscle structure, surface moisture, fat content and pigment

concentrations. Thus, from only response amplitudes an absolute measurement parameter can not be define to evaluate meat freshness.

Nevertheless, many of these effects may be corrected by using ratios of reflectance at different wavelengths or by using differences between reflectance at different wavelengths. Some relative responses look alike, such as at 550nm and 600nm, spectral responses at wavelength where temporal variation is minimal can be used like reference responses and can be compared with those temporal variations were important. The evolution of different response ratios were examined in function of storage time. Ratios of 550nm/480nm, 600nm/480nm and 550nm/630nm have important variations in function of storage time and seem to be effective parameters to evaluate freshness state of meat by spectroradiometric measurement.

Multispectral Image Acquisition and Analysis

Multispectral image experimentations were carried out in order to study the faisability of a freshness control system by artificial vision. Such a control system by imaging would provide a spatial and global view of the turkey breast and would be associated with other spatial control.
The multispectral image acquisition system (figure 5) consists of a camera with a filter wheel. The central wavelengths of spectral interference filters are comprised between 400nm and 700nm at 10nm intervals. Illumination conditions are controlled and a calibration procedure ensures to compare data between turkey samples.

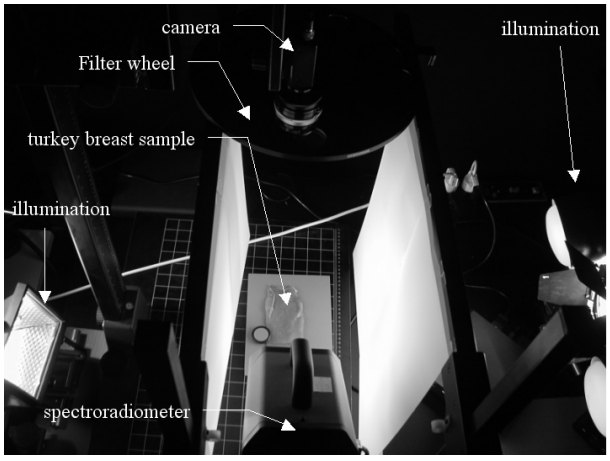

Figure 5. Schematic of multispectral image acquisition system

Multispectral image of each turkey breast sample was taken by the acquisition system, next the grey level means of two areas were extracted from each image. Spectral variations of these two means were studied in function of storage time.

The figure 6 presents the spectral response distribution of three turkey samples by multispectral imaging.

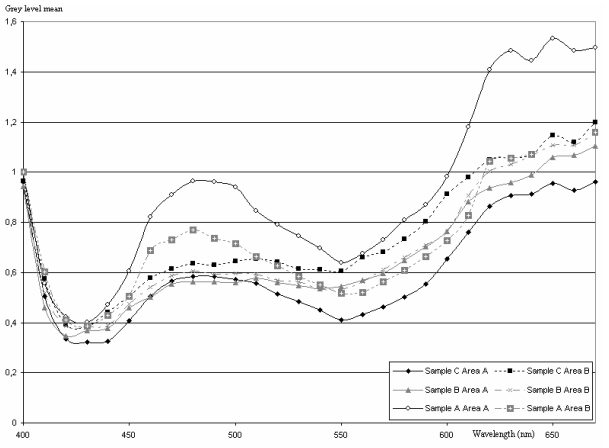

Figure 6. Spectral distribution of two responses areas (A,B) of three turkey breast samples (A,B,C)

From multispectral data, several observations are to note: firstly, global distributions of multispectral responses correspond to the distributions obtained by spectroradiometry. Secondly, the shape of spectral response is similar for a same sample. Finally, temporal variations at the wavelengths 550nm, 460nm, and 630nm are observable in function of storage time but not so important than in spectroradiometry. Nevertheless these experimentations are not sufficient to conlude and define relevant parameters for freshness determination. Further studies will be carried out in order to increse this variation sensibility and to test other illumination systems.

Conclusion

The present work was undertaken to investigate the suitability of multispectral analysis as a tool to estimate the freshness of turkey breast. Spectral measurements and analysis were carried out by spectroradiometry, spectrocolorimetry and multispectral imagery. Spectral distribution profile of turkey breast was made by spectrocolorimetric experimentations. Analysis of distribution in function of storage time has revealed relative variations on spectra. With spectroradiometric experimentations, these variations were evaluated and analyzed. Ratios of some spectral responses are related to storage time. These measurements have demonstrated the feasibility of freshness evaluation procedure from spectral responses. The extension to multispectral imagery set several difficult problems like spectral resolution and variation sensibility.

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Biography

Anne-Claire Legrand received her PhD in Image Processing from the University of Burgundy at Dijon (France) in May 2002. Her research interests focused on image processing and particularly on multi-wavelength temperature measurement by artificial vision. From June 2002 to May 2003 she was a postdoctoral fellow at Cemagref Laboratory working in the field of multispectral imaging for meat characterization. Since September 2002 she has been an assistant professor at the Laboratory LIGIV of Color Image Processing in the Jean Monnet University of Saint Etienne (France) where she is engaged in research and teaching on Color and Multispectral Image Processing.