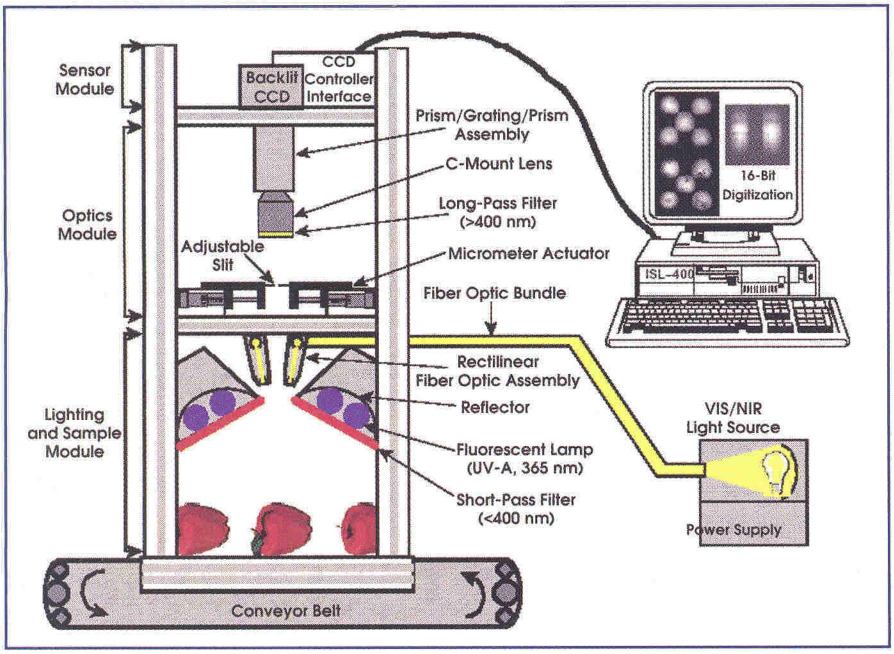
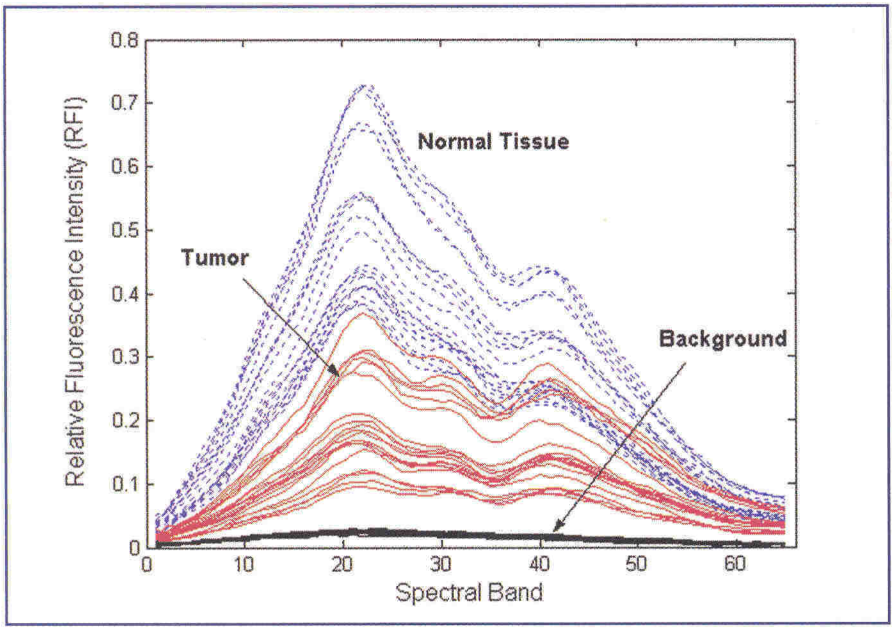
Spotting chicken tumors hyperspectrally

Spectral food inspection could provide automated detection

As far as the age-old question about the chicken and the egg is concerned, it doesn't really matter which came first. What people want, and what regulatory agencies demand, is that both be defect- and disease-free. Chicken carcasses, for instance, can have at most one tumor. Finding more than one during an inspection, according to current FDA regulations, requires removing the carcass from production.



A schematic of the hyperspectral imaging system shows the UV and visible light sources. The camera is scanned across the sample, resulting in a spectral response for every X and Y pixel captured. Images reprinted with permission from OSA.



Today, inspections are done by people working in humid and noisy environments. Inspectors may have to examine as many as 35 samples a minute for an eight-hour shift. It's a situation that can lead to repetitive motion injuries, as well as to inattention and fatigue problems. But a team of researchers from the University of Tennessee, Knoxville, the Instrumentation and Sensing Laboratory (ISL) of the Beltsville Agricultural Center in Maryland, and Myongji University in Yongin, South Korea, may have a solution. In the Feb. 1 issue of *Applied Optics*, the group described a hyperspectral fluorescence imaging system with a fuzzy inference scheme for detecting poultry skin tumors. This approach has a number of advantages.

"Photonic inspection technology is … nonintrusive and minimizes human involvement. Hyperspectral imaging techniques are useful in machine-based food safety and quality inspection for agricultural products such as chicken, fruits and vegetables," said Seong G. Kong, who is an associate professor of electrical and computer engineering at the University of Tennessee and a member of the research team.

The equipment for these tests came from the ISL, which developed it as a research tool. The hyperspectral imaging system uses both ultraviolet and visible sources from Spectronics Corp. of Westbury, N.Y., along with appropriate filters from Schott Glass Technologies of Duryea, Pa., to illuminate the sample and eliminate unwanted light. The resulting fluorescence and reflectance travel through optics and are captured by an Andor Technology electron-multiplying CCD camera. This yields a line of points and associated spectral information, which consists of an individual wavelength response across a broad spectral band. The system moves the sample and repeats the

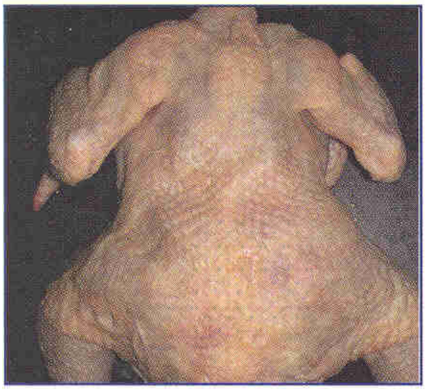
Data regarding relative fluorescence intensity vs. spectral band was used by the system to distinguish normal tissue from a skin tumor and the background.

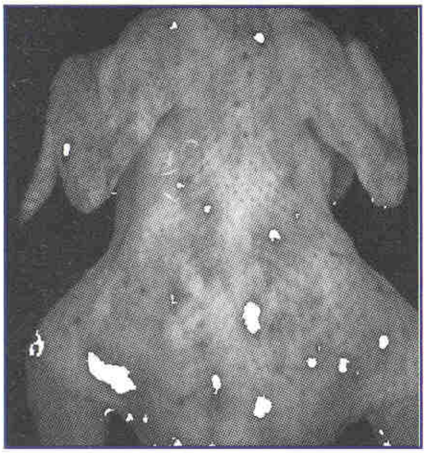
process in a line-by-line fashion until the entire sample has been covered.

The result is a hyperspectral image that can be thought of as three-dimensional. There are two spatial dimensions, X and Y, along with spectral information for a given point. Although the ISL system can produce hyperspectral images from either the reflectance or fluorescence data, the researchers decided to use fluorescence to detect the tumors. According to Kong, the decision was based on preliminary results that showed fluorescence had greater potential for picking out tumor spots from a background of normal skin.

One challenge with hyperspectral imaging is the amount of data produced. Every point carries with it a complete spectrum. The investigators settled on a sample image of 460 × 400 pixels with 65 spectral bands per location. Encoding each element with 16 bits leads to a sample poultry image of 24 megabytes. To use that information, the data must be compared with a template. Only after such training can possible tumors be spotted. This has to be done many times a minute. Consequently, because large amounts of data must be handled quickly, it must be done either on the raw image or on a compressed version.

The researchers decided to use two compression schemes and selected the first of these, a discrete wavelet transform, to compress the spatial information. The advantage of this approach is that it can be implemented through a variety of fast algorithms and customized hardware. For spectral compression, they used principal component analysis to reproduce the spectral signature of the skin with only five components, as opposed to using the entire 65-channel spectral band.





This is a chicken carcass before and after skin tumors (white spots) have been highlighted by a fuzzy inference algorithm working from captured hyperspectral fluorescence output.

"The data compression schemes reduce the data size of the original hyperspectral image to make it manageable," Kong explained.

To distinguish between normal skin and skin tumors, the researchers subjected the compressed data to a fuzzy logic-based classification scheme. When they examined the data, they noticed that normal skin had higher overall fluorescence than tumors. Tumor patches also showed a relatively strong response at band 20 — as had normal skin — and at band 45. The group used these differences to devise fuzzy rules to be used to classify a given point as tumor, normal or background.

In a series of experiments, the researchers examined a dozen carcasses and used the automated system to count the number of skin tumors. They did this using a fuzzy classifier and again with a fuzzy classifier supplemented with spatial filtering. One carcass was used for training the system and the others were examined. The researchers kept a tally of the number of tumors found, the number missed and the number falsely classified as tumors. The success rate was 82 percent, and the failure rate, those missed, was 18 percent. The number of false-positives varied, with the spatial filtering run reporting eight and the run with the fuzzy classifier alone having 16.

How this compares with the manual technique is unknown because, according to Kong, there is no real information about the accuracy of human inspectors. However, in this work there were a total of 33 skin tumors on the 11 chicken samples; only two had one or none. If a manual inspection were truly effective, the yield would be less than 20 percent. There is no way of knowing if these samples are indicative of the larger population. What is known is that skin tumors usually appear as a shape distortion and not a discoloration. They are thus difficult for either man or machine to pick out easily.

Kong reported that the next steps will be to develop, possibly in conjunction with a partner, a commercial system to aid in the automated inspection of chickens. Besides being cost-effective, such a system would have to gain regulatory approval. He noted that plans are in the works to achieve these goals. □

Hank Hogan