B17

VISION IMAGE ANALYSIS FOR ON-LINE COLOUR MEASUREMENTS ON PORK LOINS

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Pork, on-line measurements, colour, vision image analysis, automatic sorting, quality assurance.

Background
Meat colour is one of the major parameters contributing to consumer preference for individual portions of meat. The most significant parameters for meat colour in pork is the content of pigment, the ultimate pH and the oxidation state of the meat. Subjective meat colour evaluation is performed in most Danish slaughterhouses by use of the Japanese Pork Colour Standard (JPCS)(Nakai, 1975). The subjective colour sorting is carried out mainly to avoid the incidence of PSE in loins exported to Japan. The subjective evaluation of colour is influenced by light conditions, production speed, as well as human fatigue and preferences.

Objective
The work should prove that a Vision Image Analysis (VIA) system can provide fast accurate measurements of pork colour at line speeds of 600 split carcasses per hour. The ability of the vision system should be evaluated for the possibility of predicting colour after blooming of the meat, from measurements on the fresh, i.e. unbloomed, cut. Further the possibility of predicting the final subjective colour impression in the anterior part from measurements on the posterior part was to be evaluated.

Method
The muscle chosen for analysis is the Longissimus Dorsi (LD), and the site of the measurement is the anterior part. In order to enable optimum utilization of the lighter muscles, the position in production is chosen to be immediately after splitting of the carcass into the three major cuts. So the meat surface has just begun the blooming process at the time of measurement.

A VIA system is positioned along the side of the conveyor belt immediately after the shoulder is removed. The VIA system consists of a Hitachi HV-C10 three chip colour camera fitted with a remotely controlled zoom lens (Hitachi S12X7.5BMD). The camera is operated with a minimum of automatic functions e.g. without AGC, gamma and automatic white adjustment and connected for remote control from a local PC. The PC is equipped with a Colour Frame Grabber (Imaging Technology, CFG).

The meat is lit from two halogen lamps (500 W) positioned approx. 45° relative to the meat surface and the camera axis. On the conveyor belt a grey tile with equal light reflection-intensity is positioned in the vision image for calibration of white balance of the camera as well as image normalization during image analysis. When the middle of a left side of the carcass is in the correct position, image capture is initiated by the conveyor control system.

The framegrabber captures three coincident images with the size of 512 lines by 768 pixels in the colour channels Red, Green and Blue (RGB). The image algorithm is only calculating half of the lines (one field) due to the time difference of 20 ms between each field. To find the position of the loin, a typical red meat colour is identified, and the extreme position of this colour is used to determine the size and position of the loin muscle. From these data the position of a rectangle within the LD is calculated, see Figure 1. In this rectangle the mean values of Red, Green and Blue are computed. A simple formula is calculated: K1*Green + K2*Red*Blue. The two constants K1 and K2 are estimated from statistical regression. The result is a predicted value for the JPCS colour standard. Based on this value, sorting of LD into specific colour classes is possible.

124 loins were selected from one abattoir for evaluation of the VIA system. 100 of the 124 loins were randomly selected, whereas 24 were selected on the basis of a subjective evaluation to cover the extremes of loin colour. Images as well as RGB values for each of the samples were recorded. After deboning and trimming, the loins were measured by a portable Minolta instrument at the anterior end of the LD. From the posterior end of the loin, samples were cut out for laboratory analysis for content of pigment (Hornsey, 1956) and water holding capacity (WHC) determined as salt soluble protein content (Trout, 1988).

The rest of the loins were frozen and stored at -20°C until the laboratory analysis could start. After thawing, colour evaluation and measurement were performed on two slices of the loin cut between the 4th and 6th lumbar vertebrae. The slices were evaluated in white plastic trays. The trays were wrapped in oxygen permeable plastic film and left for blooming at a temperature of 1-4°C for 1 hour.

Colour evaluation was performed by a standard CIE-light at an intensity of 1000 LUX with a nominal 0° illumination and 45° viewing angle. The evaluation was carried out by five trained evaluators using the JPCS-blocks as reference. Scores given ranked from 1 to 6, with 1 as the most pale.

Colour measurements were performed immediately after the subjective evaluation by a Dataflash equipment. Settings: diffuse illumination, 8°viewing angle, 34 mm aperture, specular reflectance off, 10° standard observer, L, a, b colour scale, $BaSO_4$ equivalent white-reference-tile, four replicated measurements on each sample. pH of the homogenized samples were measured as well.

Results and discussion
The mean subjective evaluation of these selected samples had a JPCS score of 3.3 with a standard deviation of 0.62. Four of the original five evaluators performed reliably in this test so results are based on these four persons.

Linear regression on the RGB values as well as the laboratory measurements were run to test for their ability to predict the JPCS scores. The results are in Table 1.

Table 1 Prediction of JPCS colour evaluation from various measurements

Instrument	Prediction Variables	Conditions	RMSE
VIA	K1*G + K2*R*B	anterior end of LD	0.48
Minolta	L, a, b	bloomed, anterior of LD	0.47
Dataflash	L, a, b	bloomed, posterior of LD	0.30
Pigment	Hornsey	posterior part of LD	0.55
Pigm.+WHC	do. + sol. protein	do.	0.40
Pigm.+WHC+pH	do. + pH	do.	0.35

A scatter plot of the prediction from the VIA measurements is shown in Figure 2.

As the RMSE values are less than the standard deviation in the population there should be good chances that the VIA system can be used for sorting loins. This is in accordance with the impression from the trained personnel performing visual sorting in a slaughterhouse.

The VIA system performs as good as the manual Minolta measurements after allowance for the meat to bloom. Prior to deboning the posterior part of the LD is not accessible for surface measurements so the VIA system is the best potential automatic on-line measuring system for colour measurements on loins.

On-line measurement of the content of pigment by an optical insertion probe utilizing visual spectroscopy (Andersen, 1989) results in larger RMSE than the reference method. The same is the situation for Water Holding Capacity and pH measurements. In addition 3-4 insertions with each instrument is necessary to obtain decent RMSE-values and would require approx. 4 operators to follow the line speed. Even so the estimated measuring accuracy for these combined measurements will not be better than the VIA results. So in total the VIA measuring system came out as the best instrumentation for slaughterhouse colour measurements.

The dataset contains so far only very few extremely light muscles, so the actual sorting capability for the system will be verified by an experiment later this year. The stored images of the loins will also be analyzed in the search for even better predicting parameters.

Conclusion

The Vision Image Analysis system has the best potential for predicting the meat colour after deboning, trimming and blooming of loins.

The vision system calibrates itself and runs stably in slaughter environments with minimum attendance from the slaughterhouse personnel.

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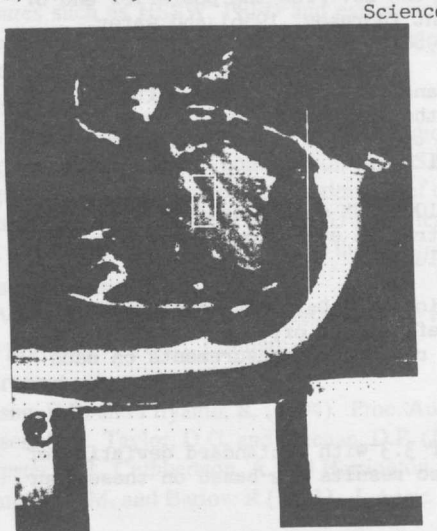

Figure 1. VIA picture of with LD muscle marked

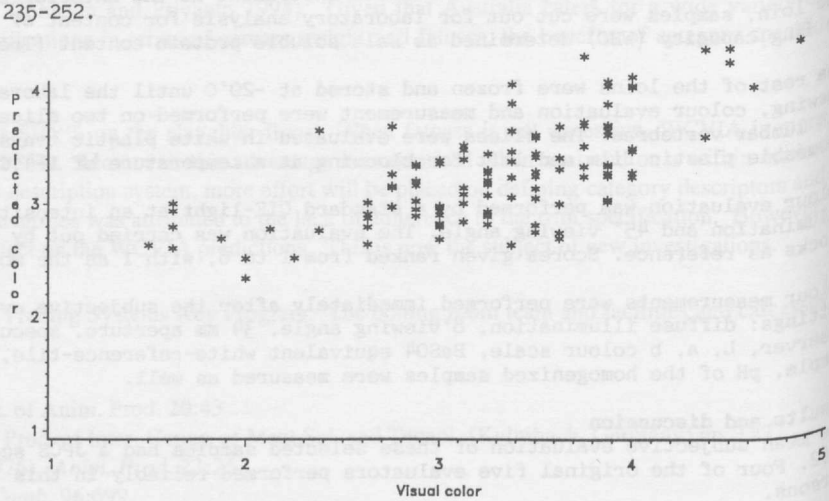

Figure 2. Prediction of subjective colour from VIA