USE OF IMAGE ANALYSIS TO VISUALLY ASSESS THE COLOUR OF CURED MEAT PRODUCTS

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INTRODUCTION The commercial shelf-life of meat products is often limited by colour changes during storage or counter display. Efficient ways to evaluate colour and/or its evolution with time have therefore been developed to help monitor product quality. In particular, traditional sensory analysis, with trained or untrained panelists, is suitable to assess colour acceptability, detect colour differences, or compare colour shades relative to each other, but the application of this method is often impossible due to the rapid discoloration of meat products upon exposure to air and light. Being instantaneous, instrumental measurements do not suffer the same limitation as sensory analysis but they give no information on the degree of acceptability of a given colour shade. Knowing this, a study was undertaken to evaluate the feasibility of assessing the colour of cured meat products by on-screen viewing of their digitalized images. By combining the advantages of traditional sensory analysis and instrumental measurements, this new method might prove ideal to follow colour changes over time.

MATERIALS AND METHODS Wiener sausages (4.5 cm flat diameter) were prepared by mixing mechanically separated chicken meat (4.2 kg) with water, sodium chloride, sodium nitrite, sodium erythorbate, soy protein isolate, and modified corn starch (500 ml, 2% w/w, 200 ppm, 500 ppm, 2% w/w, and 2% w/w, respectively; all final concentrations). Nine replicate productions were made at the rhythm of one per week. Every time, 6 separate batches of sausages were prepared, each of a slightly different colour, the colour gradient being generated by adding increasing amounts (0, 50, 65, 100, 125, 150 ppm) of hydrosoluble red carmine to the formula. The sausages were then cooked to 68°C (core) in 72°C circulating water, cooled to 30°C, and subsequently stored at 1°C until colour assessment (within two days).

The relative colour differences between slices (2 mm thick) of the sausages containing 0, 50, 100, 125, or 150 ppm of red carmine and slices of the reference sausages (containing 65 ppm of carmine) were compared using the R-index procedure. The procedure involved serial presentations of sausage slices to panelists (6 females, 4 males, with no detectable colour vision problem), two slices at a time. One of the slices always came from the reference sausage and was identified as such. The other slice was unidentified and could either come from the reference or from any other sausage. The panelists were then asked to state if the unidentified slice was identical, probably identical, probably different, or different from the reference slice. Assuming that the numbers of times that slices from a particular sausage were found identical, probably identical, probably different, or different from reference slices were *a*, *b*, *c*, and *d*, respectively, and that *e*, *f*, *g*, and *h* were the corresponding numbers when the unidentified slice was the reference, the relative difference between the colours of unidentified and reference slices is given by the R-index, $R = [d(e+f+g)+c(e+f)+be + \frac{1}{2}(ae+bf+cg+dh)] / (a+b+c+d)(e+f+g+h)$. The same procedure was used to evaluate colour differences between digitalized pictures of the sausage slices. Also, the a* value of the Lab* colour coordinates was determined on randomly selected slices from the different batches, as a measure of control.

The colour of the sausage slices was evaluated in a standard lightbooth under D65 lighting (about 1000 lux). Evaluation sessions lasted 30 min per panelist. One reference slice and one unidentified slice were shown to the panelist every 30 s, for a total time of 5 s, the 25 s delay between successive presentations being required to minimize the effect of iconic memory. Presentations were done in a pre-randomized order, so that slices from the six sausage formulas (including the reference) were compared 10 times each to the reference, during the whole evaluation session.

The image analysis system consisted in an IBM compatible personal computer, equipped with a 90 MHz pentium micro-processor, 64 Mb of RAM, a 2 Gb capacity hard disk, and a high quality colour screen (16,000,000 colours; 1280 x 1024 pixel). The luminance and contrast of the screen were adjusted manually to obtain a balanced image, then blocked with silicone glue for the rest of the study. Colour calibration was subsequently done following the preset program provided with the image analysis software and the calibration parameters were saved for future use. In preparation for the colour evaluation on digitalized images, 10 freshly prepared slices of each sausage formula were first scanned and the scanned images of individual slices were stored in separate files. These images were later recalled and recombined to prepare a screen show which automatically presented pairs of slice images for 5 s, every 30 s, in a similar way as for the colour evaluation of sausage slices.

RESULTS AND DISCUSSION In order to obtain meaningful results, the range of colour shades presented to panelists had to be such that the difference between the slices or images being compared would sometimes be difficult to detect, while being easily perceived other times. The concentrations of red carmine used in formulation was therefore selected in preliminary trials so that, when slices from the six different batches were ranked in the order of increasing carmine concentration and observed simultaneously, the differences between adjacent slices would be hardly detectable, while the difference between the extremes would be evident. Obviously, the experiment would only be successful if the small shade differences between sausages from the various batches could be constantly obtained, through the 9 replicate production runs. This condition was essentially (but not absolutely) met since, with a few exceptions, the a* values of the adjacent slices were found statistically different ($P \leq 0.05$) from each other (Figure 1).

The R-index values associated with the sausages containing various amounts of carmine, in relation to sausages from the reference batch (65 ppm carmine), are shown in Figure 2, for both the traditional sensory evaluation technique (viewing of sausages slices) and the on-screen viewing of digitalized images. The traditional technique always yielded higher numbers for the R-index values than did image analysis but statistical analysis indicated an interaction between evaluation methods and sausage production runs so that the R-index values were only statistically different 73% of the time, i.e. for 33 out of 45 (carmine concentration)*(production run) combinations (results not shown). This points to an overall trend for on-screen observation of the digitalized images producing systematically lower R-index values than traditional sensory analysis.

Since the R-index, by its nature, evaluates the extent of the difference between a given sample and the reference, the fact that higher R-index values were generally obtained by traditional sensory analysis suggested that judges perceived greater colour differences between samples and the reference when looking at sausage slices rather than when looking at digitalized images. This further implied that traditional sensory analysis was better suited than image analysis to detect subtle colour differences. A thorough examination of the detailed results, however, indicated that these conclusions were wrong.

All results combined (judges and production runs), the colour of the sausage containing no carmine was found to be different from the colour of the reference sausage (65 ppm carmine) at the same frequency in traditional sensory analysis (812/820 times) than in image analysis (847/850 times; results not shown). The colour difference of 2.7 a* units was easily and equally detected by both method. When the colour difference between the sausage being evaluated and the reference sausage was smaller (1 a* unit, sausage containing 100 ppm carmine), the colour difference was detected less often, 618/829 times by traditional sensory analysis and 634/850 times by image analysis, but still roughly equally well by both methods. When, however, judges were asked to compare the reference sausage to itself (no colour difference), they tended to perceive a difference in shade (inexistent) much more often (330/850 times) by image analysis than by traditional sensory analysis (133/820 times), artificially resulting in higher R-index values for the traditional method, through the actual index calculation. This suggested that the lower R-index values generally obtained by image analysis, compared to traditional sensory analysis, might actually reflect a better ability of the former method to discriminate between minute differences in shade.

This was later confirmed by the results of variance analysis. Within each method, tests were performed to determine if the R-index values of sausages containing different amounts of carmine were different. Knowing the actual colour difference between the sausages, expressed in a* units, the results of variance analysis could then be used to evaluate the respective ability of the two evaluation methods to discriminate sausages on the basis of colour. A summary of the results is presented in Table 1 and demonstrates that, while none of the method could detect colour differences as small as 0.7 a* unit, image analysis was constantly better than traditional sensory analysis in detecting colour differences in the 1-1.8 a* range.

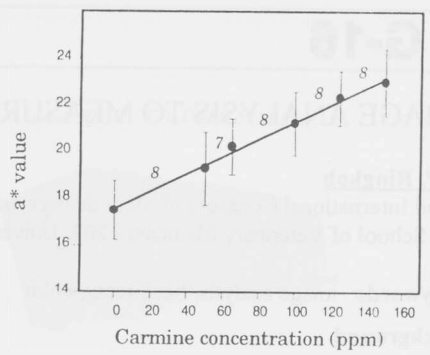

Figure 1: Mean a* values of sausages from the 9 production runs (± SD). In italic are the numbers of times, out of 9, that the a* values of adjacent sausages were found to be statistically different ($P \leq 0.05$).

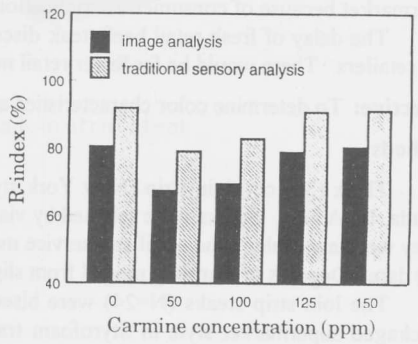

Figure 2: R-index values of sausages obtained by the two evaluation methods.

Table 1: Compared ability of the two evaluation methods to detect colour differences using the R-index.

	Sample pair being compared			
	0-50 ppm carmine	100-125 ppm carmine	100-150 ppm carmine	125-150 ppm carmine
Δ a* [1]	1.7	1	1.8	0.7
Method				
traditional	4/9 [2]	3/9	3/9	0/9
on-screen	7/9	5/9	6/9	0/9

[1] Colour difference between the sample and the reference sausage,
[2] Number of times out of 9 that the R-index of the samples being compared were found to be different.

CONCLUSION The widespread use of image analysis systems for the assessment of colour is still limited by the imperfections of the colour calibration tools currently available. From the results of this study, however, it is obvious that, once the calibration problems are solved, image analysis will be a very powerful means to efficiently and precisely monitor the colour of food, and in particular of meat products, during processing and storage. Obviously, further studies are now required to evaluate how well image analysis will perform, compared to traditional sensory analysis, in a wide range of experimental situations (difference testing, similarity testing, ranking, etc.).