COLOUR AND COLOUR STABILITY OF HAMBURGERS PREPARED FROM ELECTRICALLY STIMULATED, HOT VS COLD BONED, CLOSELY TRIMMED BEEF

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INTRODUCTION

Several meat quality characteristics observable in the processing plant and supermarket, or measurable in the laboratory are known to be closely related to the consumers' appreciation of meats. Among these the colour of meat is of primary importance for the retailer as it largely determines the consumers' inclination to buy one product or brand rather than the other (Hood and Riordan, 1973). The colour of meat depends on a number of independent variables important in marketing, e.g., animal age, pre- and post-slaughter handling and the display environment (McDougall, 1977). All of these interfere heavily with the pure physics of colour observation by individuals or colour-analysing instruments. Therefore, novel ways of processing carcasses into meats need to be evaluated carefully as to their impact on meat colour.

The colour of meat primarily depends on the concentration of the pigment myoglobin which can exist in three forms: the purple (reduced) myoglobin (Mb), the cherry-red (oxygenated) oxymyoglobin (MbO) and the greyish-brown (oxidized) metmyoglobin (MMb). These three forms are constantly being interconverted. When the surface of meat is exposed to air, oxygen will penetrate into the interior, the oxygen diffusion being deeper the longer the meat is exposed. Below the layer of MbO, a thin Mb layer exists where the partial pressure of oxygen is too low for oxygenation to occur. Beyond that a thin layer of Mb is oxidized to MMb, which will gradually shift from interior to surface, thus causing the so-called 'fading' of meat (Seideman et al., 1984). Several factors determine the accumulation of MMb on the meat surface and hence the stability of meat colour, e.g. rates of oxygen-diffusion (Brooks, 1938) and -consumption (Atkinson and Follett, 1973), (auto) oxidation (Lawrie, 1979) and the enzymatic reduction of MMb (Hood, 1980; Ledward, 1985; Renerre and Labas, 1987). Extrinsic factors such as pH decline and temperature, water-holding capacity and muscle structure affect how colour is perceived (McDougall, 1977).

Several meat processing procedures markedly influence both intrinsic and extrinsic colour determinants. Two major ones are meat comminution and salting, the former one destroying the reducing system and thus promoting the rapid formation of MMb (Ledward et al., 1977), the latter one exerting a strong pro-oxidant effect (Huffman, 1980).

Many of the afore-mentioned factors that determine colour stability are affected by accelerated processing of meats. Firstly, electrical stimulation will induce a rapid early post-mortem pH decline, secondly hot boning accelerates the chilling rate, and finally pre-rigor comminution and salting largely determine the chemical form of Mb, rate of ATP breakdown and glycolysis and thus the water-holding capacity and light reflectance characteristics.

In earlier studies we investigated the influence of electrical stimulation and hot boning on the colour (stability) of intact bovine longissimus and psoas major muscle (Van Laack et al., 1989; Van Laack and Smulders, 1989a) and ground beef of a relatively high fat content (Van Laack and Smulders, 1989b). The purpose of the present study was to assess the impact of accelerated processing on the colour stability of a comminuted, pre-salted product prepared from beef from which all visible fat had been trimmed off.

MATERIALS AND METHODS

Eight Friesian Holstein cows, 3-5 years old, were stimulated electrically (85 V, 14 Hz, 30 s) within 5 min post mortem. At approximately 1 h post mortem the sternomandibularis muscles of randomly selected carcass sides were hot boned, cut up in

chunks, ground through a 3 mm plate, mixed with a hamburger-mix (Verstegen, Rotterdam, The Netherlands) resulting in a salt concentration of 1.8%, and blended in a Hobart blendor for 3 min. Using a mould, hamburgers (1.5 cm thick, 8 cm diameter) were hand-pressed and frozen at -40°C and finally stored at -20°C in card-board boxes. An identical procedure was followed for cold-processing of hamburgers, i.e. after the remaining carcass side had been chilled at -1 to -4°C, air velocity 3 m/s, during the first 90 min, whereafter the carcass was stored at 1±1°C, air velocity 0.5 m/s for 24 h.

Before freezing hamburgers were sampled for microstructural study using the methodology described by Koolmees et al. (1989).

Sixteen hamburgers per treatment group (2 samples per carcass-side) were thawed and allowed to bloom at 2±2°C for 2 days whereafter they were displayed for 7 days at 1±1°C under continuous illumination with a 300-400 Lux lamp (Philips TLC95). At 0, 2, 4 and 7 days of display L*, a*, b* values and spectrum (400-700 nm) were analysed instrumentally by means of a Hunter Labscan SN12244; 10° Standard Observer, D65 illuninant, 50 mm opening, calibrated with black and white tiles. Significance of differences were tested with the Student-t-test (paired where appropriate).

RESULTS AND DISCUSSION

Figure 1 includes the Hunter CIE-Lab values of hot and cold processed hamburgers during one week of display at 1±1°C.

Throughout the storage period L*, a* and b* values were higher in hot than in cold processed beef burgers, which differences were significant ($p<.05$) in all instances but two (a* values at day 0 and 2). The higher values for Hunter L*, denoting a brighter colour, are in agreement with earlier findings on pre-rigor ground (Van Laack and Smulders, 1989b) and flaked beef (Van Roon et al., unpublished results cited by Smulders et al., 1987).

Hot boned, intact beef and pork muscles almost invariably exhibit a darker colour than cold boned muscle

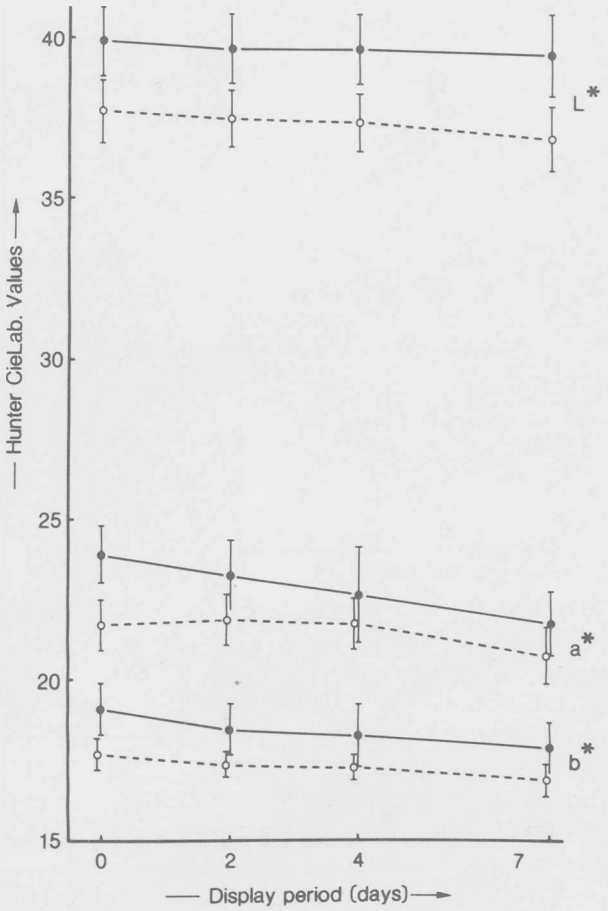


Fig. 1 Hunter CIE-Lab values of hot- (•) vs cold- (o) processed hamburgers during 1 week of display at 1±1°C

after one week of refrigerated vacuum storage (Smulders et al., 1988). This has been attributed to the superior waterholding properties of pre-rigor excised meat which might reduce light reflectance and, to a lesser degree, to protein denaturation caused by faster chilling (Taylor et al., 1980-1981). That the situation is reversed in comminuted beef with a relatively high percentage of fat was suggested to be the result of pre-rigor ground beef having soft warm fat which is dispersed through the product as small droplets; in cold processed beef burgers the solid fat had a more granular appearance (Van Laack and Smulders, 1989b). In the present experiment we carefully trimmed off all visible fat from the muscles to achieve a low fat content. Fat content of the blend was 12% (assessed through extraction) in both hot and cold processed burgers. We hoped that with such a low fat per

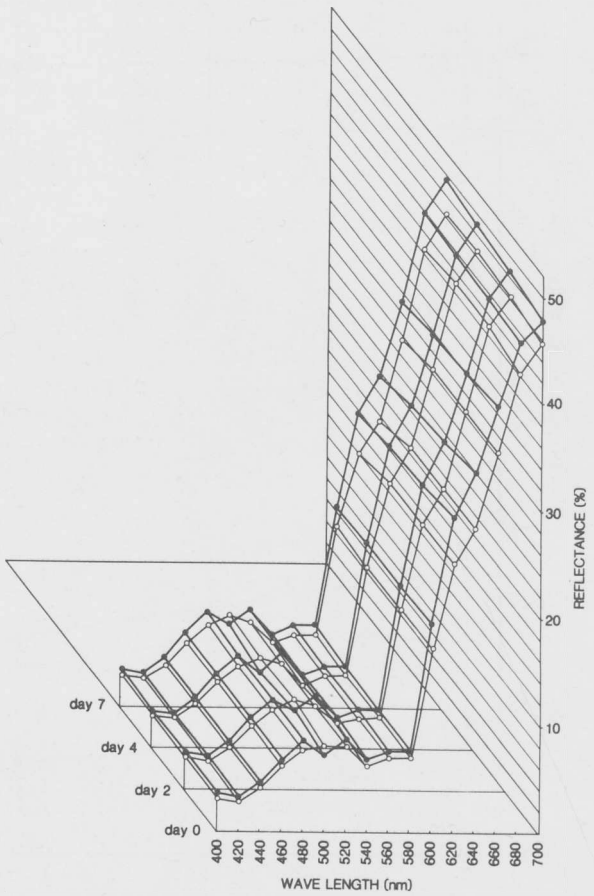


Fig. 2 Reflectance spectra of hot- (•) vs cold- (o) processed hamburgers during 1 week of display at 1±1°C

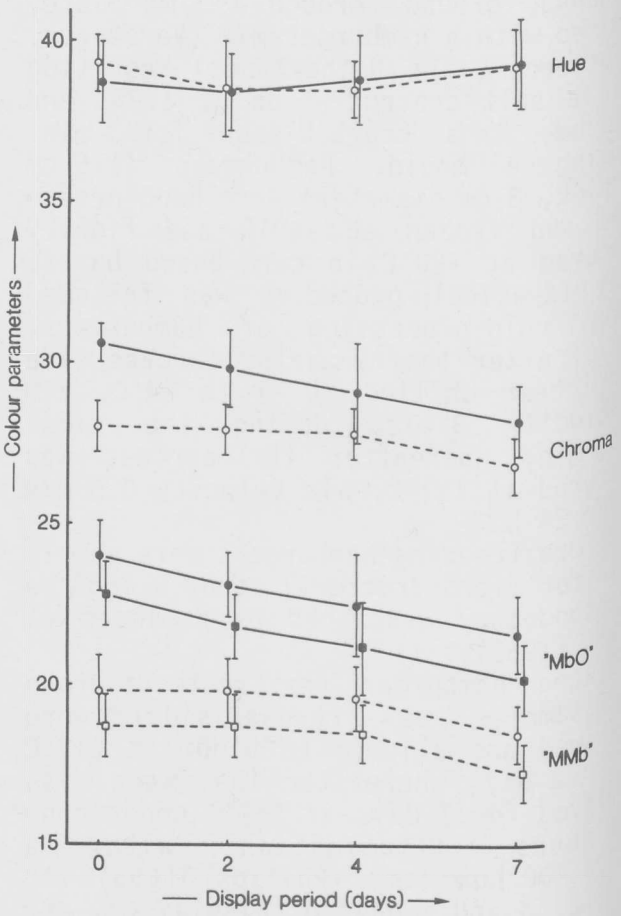
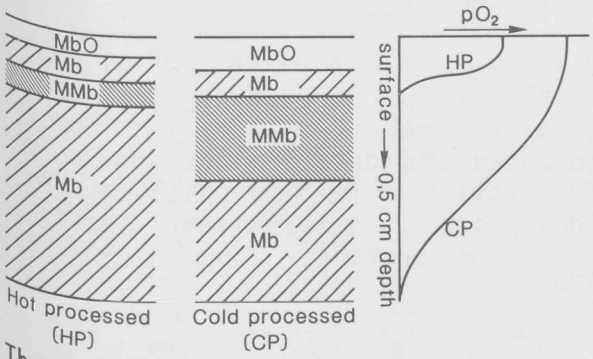


Fig. 3 Hue and chroma values, and % Reflectance (Δ630-580 nm: MbO; and Δ 630-525 nm: 'MMb') of hot- (•) vs cold- (o) processed hamburgers

centage structuraldifferences would interfere less seriously with light reflectance. Yet, light-microscopical examination clearly indicated that the fat in hot, as opposed to cold processed burgers had coalesced in fat channels, finely dispersed through the product. This has likely altered the smoothness of the surface and thus increased the light scatter in hot processed burgers as also observed by Aby-Bakar et al. (1988). Other investigators (e.g. Jacobs and Sebranek, 1980; Seman et al., 1986) found that hot processed ground beef had a darker appearance. One would expect to observe this since hot processed burgers have superior waterholding properties (Van Laack & Smulders, 1989b). It should be realized, however, that, as opposed to the afore-mentioned American studies, the hamburgers in our study were composed of one single ground muscle. It is possible that between-muscle differences account for discrepancies in results since the degree of post mortem protein denaturation differs considerably between muscles, depending on pH and temperature decline and thus on chilling rates. In our study we used sternomandibularis muscle which, on account of its position in the carcass, will chill very fast after hot boning as well as on the cold-to-bone carcass. The MMb reducing activity may therefore have been quite similar for both processing methods (McDougall and Allen, 1986).

Figure 2 is a three-dimensional representation of the light reflectance of hot vs. cold processed beef burgers at different wave lengths, as it changes during one week of refrigerated display. If the observed difference in colour of hot vs. cold processed hamburgers would simply be a matter of altered structure one would expect the reflectance spectra for both types of

products to run more or less parallel. The fact that the curves diverge, converge and even cross at particular wave lengths seems to indicate that the relative proportions and/or location of MbO, Mb and MMb may have been affected by the method of processing. In an earlier study (Van Laack et al., 1987) it was substantiated that the oxygen consumption is higher in pre-rigor than in post-rigor meat. This might lead to a thinner surface layer of MbO. In addition, the lower partial pressure of oxygen in pre-rigor beef, through increasing the redox potential, will increase the reducing capacity in the hot processed hamburgers. This will lead to a thinner layer of MMb and a relatively thick surface layer of Mb (George and Stratmann, 1952). It is tempting to speculate that the relative contribution of Mb to the total reflectance accounts for the higher reflectance values observed in hot processed hamburgers as, strictly for the purpose of illustration of this argument, is visualized below.



The reflectance spectra of muscle pigments are well-documented (Kropf et al., 1976; Hunt, 1980). The total reflectance of meat and meat products being a composite (not simply a sommation!) of the reflectances of the pure pigments, might also explain why only at 500 nm the total reflectance is lower for hot- than for cold processed hamburgers, for it is well possible that at this particular wave length the contribution of, for instance, MMb is less important than that of Mb or MbO.
Particularly at wave lengths >600 nm the reflectances of the hot processed hamburgers decrease more rapidly than those of the cold processed ones (note the difference in convergence of the lines connecting the reflectance values at different storage times on the one hand and the reference lines parallel to the time-axis on the other). This observation indicates that, in contrast with intact muscle (Van Laack et al., 1989; Van Laack and Smulders, 1989a) the colour stability of hot boned, comminuted beef is less stable than that of cold boned comminuted beef. A further substantiation for this is found in the observation that the values for chroma [C*, generally considered a useful parameter to describe colour changes in more descriptive terms (McDougall, 1977)] decrease more rapidly in hot than in cold processed hamburgers (see Figure 3).
In spite of these contrasts it should be recognized, however, that all products, irrespective of way of processing, were very attractive in colour as is reflected by C* values (ca. 27 and higher throughout storage) approximating the reference values generally associated with an attractive, brightly-red, colour (McDougall and Allen, 1986). The fact that display conditions (strict storage at 1±1°C) were almost ideal to preserve colour-stability has undoubtedly contributed to this.

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