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MYOGLOBIN DENATURATION AS AN INDICATOR OF INTERNAL COOKED GROUND BEEF COLOR

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Introduction

Internal cooked color traditionally has been used by consumers to determine cooked meat product doneness. However, two phenomena (premature browning and persistent pinking) prohibit the use of internal cooked color to indicate doneness of ground beef. Premature browning has been defined as an internal well-done appearance when endpoint temperatures ensuring safety have not been reached, thereby creating a food safety issue. Persistent pinking is remaining redness/pinkness after the product has been cooked to a safe endpoint temperature. This often leads to overcooking, creating a food quality concern.

In ground beef, consumers often accept a patty with a brown internal color, which may not have been cooked to a safe temperature, while rejecting a patty with a pink internal color that was cooked to a safe temperature. For that reason, premature browning and persistent pinking present issues that food-service establishments must confront with regard to product safety and customer acceptance.

Marksberry (1990) first noted that some ground beef patties had a well-done appearance at much lower temperatures than those needed to ensure safety. Hague et al. (1994) termed this occurrence "premature browning" (PMB) and demonstrated that internal cooked color was not always a reliable indicator of patty doneness. Warren et al. (1996b) examined several chemical properties of ground beef that developed PMB and concluded that PMB was related to the oxidative state of myoglobin in raw product. In examining the importance of myoglobin oxidative state, Warren et al. (1996a) showed if oxidized myoglobin was present in the interior of the raw patty, the interior cooked color was brown. If reduced myoglobin was present, an expected reddish-pink cooked color was observed. Hunt et al. (1999) further found patties with DMb in the interior appeared red and undercooked at 55°C becoming browner with increasing temperature. Additionally, patties with OMb and MMb in the interior created a brown internal cooked color after being cooked to 55°C.

Just as PMB creates unreliability in determining doneness, so does persistent pinking. Trout (1989), and Mendenhall (1989), indicated that as pH increased, myoglobin became more heat stable, resulting in persistent pinking (Kropf and Hunt, 1998). *Nitroso pigments*, found in cured meat products, may also cause persistent pinking (Cornforth, 1994). Hunt et al. (1999) also demonstrated that the redox form of myoglobin affects persistent pinking.

The effects of rapid cooking on internal cooked color development of ground beef are unknown. Brewer et al. (1999) cooked ground beef patties at two rates, 0.7° or 3°C/min, to endpoint temperatures of 55, 60, 65, 70, 75 or 80°C. They found no differences in instrumental or visual color. However, no research data exist on the effects of very rapid cooking rates, such as those used widely in the American fast food industry, the subject of this research. Furthermore, there are no literature reports on the amount of myoglobin that must denature for a ground beef patty to have a well-done internal appearance.

Objectives

Our objective was to determine the role of myoglobin denaturation as an indicator of cooked ground beef patty doneness as influenced by cooking rate and endpoint temperature.

Methodology

Raw ground beef patties (113.5 g, 11.5cm × 12.5cm × 0.8cm) containing 19.7% fat and having a pH range of 5.9 to 6.1, were formulated, vacuumed packaged, and never frozen. Patties contained essentially 100% DMb on the interior, which should give the expected change in internal cooked color from red to pink to brown (Hunt et al., 1999). After 5d, ground beef patties were cooked to one of five endpoint temperatures 65.6, 71.1, 76.7, 82.2 or 87.8°C using either a double-sided grill (1.0°C/sec, very rapid rate) or flat single-surface grill (0.2°C/sec, slow rate). As patties reached their assigned endpoint temperature, they were removed from the cooking device and placed into a bag, which was then placed in an ice bath to limit post-cook temperature rise. Cooled patties were bisected parallel to the patty surface and CIE L* (lightness), a* (redness), and b* (yellowness) values for Illuminant A were obtained. A trained visual panel (n = 3) evaluated the internal cooked color of patties to the nearest 0.5 using the following 5-point cooked-color scale (Marksberry et al., 1993): 1 = reddish-pink center, pink border, tan edge; 2 = pinkish-red center, pink to light brown/tan to outer surface; 3 = slightly pink center, light brown to tan edge (medium); 4 = tan/brown center and edges, no evidence of pink; 5 = dry, brown throughout (well done).

Myoglobin concentration was quantified on raw and cooked patties by extracting myoglobin using a method described by Warriss (1979) and modified by Hunt et al. (1999). Total myoglobin content in raw patties was compared to total undenatured myoglobin in cooked patties to determine the total percent myoglobin denatured. The study was designed as a completely randomized 5 × 2 factorial consisting of 5 temperatures and 2 cooking rates with 5 replications. Data were analyzed using analysis of variance in the MIXED procedure of SAS (2001).

Results & Discussion

Rapid cooking had a profound impact on instrumental cooked color. At endpoint temperatures below 82.2°C, rapidly-cooked patties had greater ($P < 0.05$) a* values than slow-cooked patties (Fig. 1-a) with the greatest difference in a* value occurring at 65.6°C. While rapidly-cooked patties had greater a* values than slow-cooked patties at 87.8°C, patties cooked using either rate were least red of all treatment combinations at this endpoint temperature. Patties cooked rapidly to 71.1°C were less red than 65.6°C and redder than 76.7°C ($P < 0.05$), while cooking to an endpoint temperature of 82.2°C was similar to 76.7 and 87.8°C ($P > 0.05$). Cooking rapidly to temperatures of 82.2 and 87.8°C resulted in a minimum a* value indicating that little if any pink color remained. Slow-cooked patties had similar ($P > 0.05$) a* values among endpoint temperatures below 87.8°C, with patties cooked to 87.8°C being the least red ($P < 0.05$). As all slow-cooked patties had low a* values, it reasons that they all probably would have a similar well-done appearance. Regardless of cooking rate, a* decreased as endpoint temperature increased.

Visual color data reflected those of instrumental color data. Rapidly-cooked patties were more red/pink ($P < 0.05$) than slow-cooked patties at all endpoint temperatures except 87.8°C (Fig 1-b). Only at 87.8°C were rapidly- and slow-cooked patties of equal appearance ($P > 0.05$). All slow-cooked patties appeared well done (visual score > 4.0) even at 65.6°C, indicating that premature browning had developed. Patties cooked rapidly to 71.1 and 76.7°C were still slightly pink on the interior (visual score < 4.0). Rapidly-cooked patties appeared well done at endpoint temperatures of 82.2 and 87.8°C.

Percent myoglobin denaturation provided an objective measure of pigment denaturation during cooking and accentuated visual and instrumental assessments of internal cooked color (Fig. 1-c). Slow-cooked patties had essentially 90% or greater denatured myoglobin at all endpoint temperatures corresponding with their well-done appearance. A greater range of values was seen in rapidly-cooked patties, similar to a* and visual color data. Myoglobin denaturation was less ($P < 0.05$) for rapidly-cooked patties than slow-cooked patties at endpoint temperatures of 76.7°C and below, resulting in a redder, less well-done internal appearance. At endpoint temperatures of 82.2 and 87.8°C, both cooking rates were similar ($P > 0.05$) in myoglobin denaturation. Both temperatures resulted in greater than 90% myoglobin being denatured, which was reflected in the decreased a* and greater visual scores.

Instrumental (Fig. 2-b) and visual (Fig. 2-a) color were highly correlated with myoglobin denaturation (r = -0.91 and 0.88, respectively). Through regression analysis, it was determined that a patty with approximately 80% myoglobin denaturation would result in a well-done internal appearance (visual score > 4.0) with a corresponding a* value of 12.4. Thus, approximately 80% myoglobin denaturation is needed to result in a well-done internal appearance regardless of cooking method. This will be achieved at lower temperatures with slower cooking rates and at higher endpoint temperatures with more rapid cooking rates.

Conclusions

Percent myoglobin denaturation appears to be an excellent objective indicator of internal cooked appearance, with approximately 80% myoglobin denaturation resulting in a well-done internal appearance. Cooking rate and endpoint temperature greatly influenced the amount of myoglobin denatured and resultant internal cooked color of ground beef patties. Very rapid cooking required greater endpoint temperature than necessary for safety to achieve a well-done appearance, while slow-cooking resulted in PMB. This study reaffirms that internal cooked color is not an adequate indicator of product doneness and/or safety.

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Figure 1: Internal (a) a*(redness), (b) visual color, and (c) percentage myoglobin (Mb) denaturation of ground beef patties, slowly or rapidly cooked to assigned endpoint temperatures. Raw patties contained predominately deoxymyoglobin in the interior when cooked. Means within an endpoint temperature (a, b) or within a cooking rate (w, x, y, z) differ (*P* < 0.05). n = 5 patties/treatment combination.

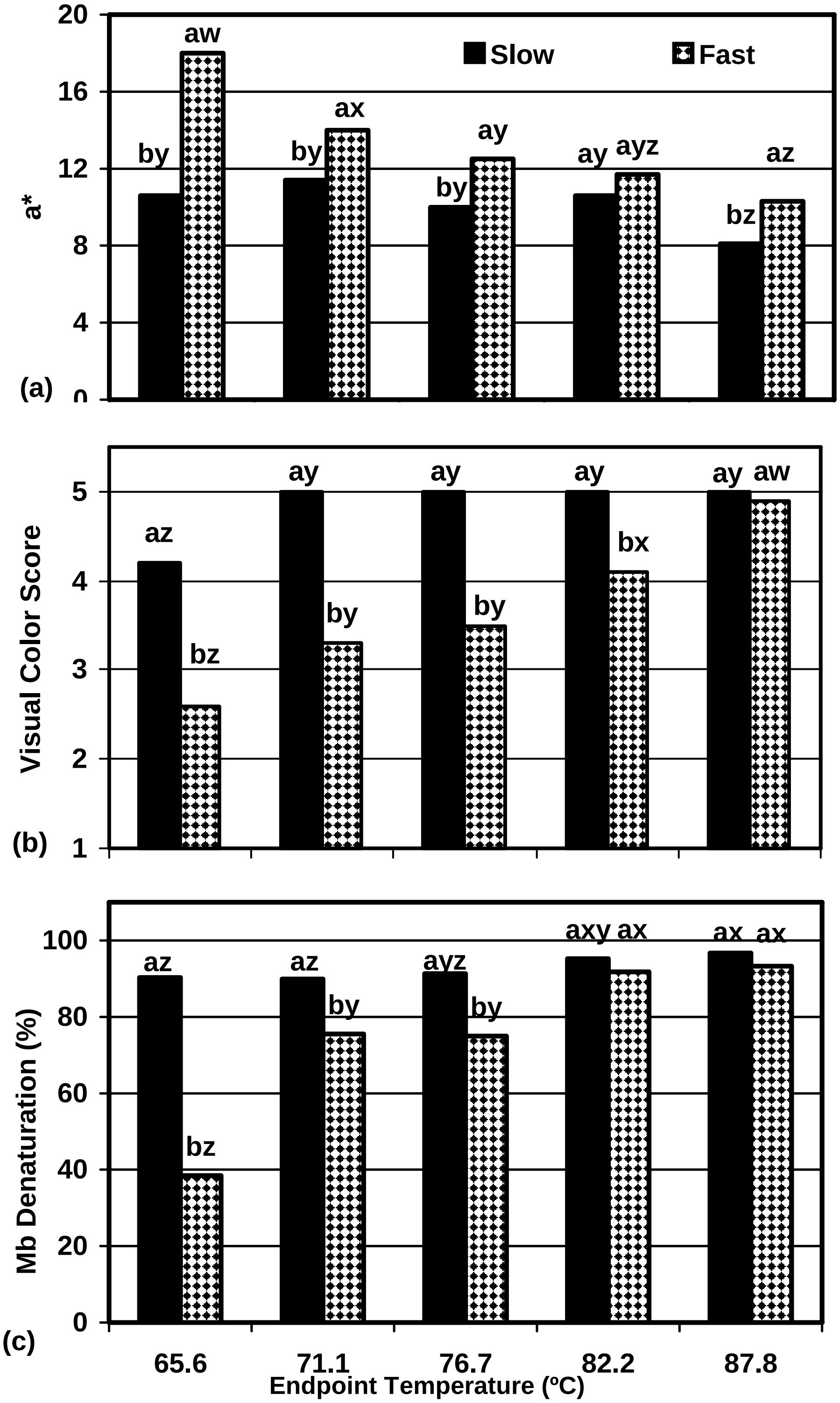

Figure 2: Regression analysis predicting myoglobin denaturation for (a) visual color and (b) a* (redness) values of ground beef patties, slowly or rapidly cooked to assigned endpoint temperatures.