C78

EFFECTS OF MYOGLOBIN FORM ON INTERNAL COOKED COLOR DEVELOPMENT IN GROUND BEEF

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ABSTRACT

To determine the effects of myoglobin form on internal cooked color development in ground beef, patties were made to contain essentially 100% deoxy-(DMb), oxy-(OMb), or metmyoglobin (MMb) and cooked at 165°C to 55, 65, or 75°C. Only patties with DMb appeared red and undercooked at 55°C, and the color of these patties became progressively more brown at 65 and 75°C. Patties with OMb and MMb were brown at 55°C and could easily be mistaken as being cooked enough to kill pathogenic bacteria. If doneness of ground beef is based on internal cooked color alone, it is valid only if the pigment at time of cooking is DMb. If the pigment is either OMb or MMb, patties will appear internally prematurely brown at lower than expected temperatures, thus creating a food safety risk.

INTRODUCTION

Many consumers use internal cooked appearance of ground beef patties to evaluate doneness. Hague et al. (1994) indicated that internal color was not always a reliable indicator of doneness because of an unusual cooked color pattern described as premature browning (PMB, Marksberry 1990), whereby some patties developed a cooked, well-done appearance at temperatures much lower than expected. Warren (1994) concluded that PMB was related to the oxidative state of the meat; if MMb was present in the patty interior, PMB developed, and if DMb was present, a normal cooked color developed. The objective of this study was to determine the effects of myoglobin form on internal color development of ground beef cooked to three endpoint temperatures. Underlying this specific objective was concern for food safety and the possibility that consumers could look at ground beef, conclude that it was fully cooked, and consume it, even though it had not been heated sufficiently to kill *E. coli* 0157:H7 or other pathogens.

MATERIALS AND METHODS

Selection of meat: The semimembranosus, adductor, semitendinosus, biceps femoris, and quadriceps muscles and subcutaneous fat were obtained 5 days postmortem from six bull carcasses of Norwegian Red Cattle. Animal identity was maintained for each group of muscles, but the subcutaneous fat was combined into one batch without animal identity. The lean from each carcass was ground through a 13-mm plate and mixed with fat to about 20% fat blends. These blends then were ground twice through a 4-m plate. **Patty and myoglobin-form production:** A third of each batch was made immediately into 100 g patties with a patty maker. The pigment in these patties was essentially 100% OMb. Uncovered patties were frozen at -40°C, vacuum packaged, and stored at -40°C. MMb was produced in another third of each batch of meat by using portions flattened to ≤5 mm, packaging in nitrogen and 2% oxygen, and storing at 2°C. At 48 hr, the thin layers of meat, which appeared to contain nearly 100% MMb, were formed into patties, frozen, vacuum packaged, and stored as described previously. The last third of the meat was stored in vacuum at 2°C for 48 hr to fully reduce the pigment to DMb. Patties were formed, immediately covered with oxygen-impermeable film, frozen, vacuum packaged, and stored at -40°C. **Proximate analysis, pH, and microbial:** Patties were analyzed for moisture, fat, and protein. pH was measured on a blended solution (1:5 water to meat). Total viable aerobic counts were determined using plate count agar and incubation at 20°C for 4 days. **Cooking procedures:** Patties were thawed overnight at 4°C and cooked on a grill at 165°C for 3.3, 4.2, or 5.8 min to endpoint temperatures of 55, 65, or 75°C, respectively. Internal temperatures were monitored using a digital thermometer by intermittently inserting a 1-mm dia thermocouple. Differences in cooking time and losses (data not shown) among patties with different myoglobin forms at each endpoint were small, indicating standardized cooking conditions. **Color measurement:** External color of uncooked patties with each myoglobin form was evaluated 3 min after patty formation. Internal color was evaluated immediately after the patties were sliced through their horizonal centers to yield two circular halves; this color represented the pigment state in uncooked patties at cooking. Four panelists visually evaluated patties that were illuminated with 1614 lux of Osram Lumilux Warm White fluorescent lighting. External and internal uncooked colors were scored to the nearest 0.5 using 1 = purple red (DMb), 2 = reddish purple, 3 = bright red (OMb), 4 = reddish tan or brown, and 5 = tan or brown (MMb). Cooked patties were cooled for 3 min at room temperature, sliced through their horizonal centers and evaluated to the nearest 0.5 point, where 1 = dark red to purple, uncooked appearance; 2 = bright red; 3 = very pink; 4 = slightly pink; and 5 = tan, no evidence of pink. Instrumental color of raw and cooked patties was measured using a Minolta CR 300 Chromameter to record CIE L*, a*, and b* values for Illuminant C, and the saturation index $(a^{*2} + b^{*2})^{1/2}$ was calculated. **Statistical analysis:** Six replications (animals) were conducted, and data were analyzed using ANOVA with a split-plot design where myoglobin form was the whole plot, and endpoint temperature was the split-plot.

RESULTS AND DISCUSSION

Raw patties used in this study had the following properties: pH 5.65, 63.1% moisture, 17.9% fat, 18.4% protein, and an aerobic plate count of 4.2×10^4 organisms per g. Thus, these patties were typical of those consumers often purchase for home use. For all color traits studied, significant interactions occurred between myoglobin form and endpoint temperature.

The validity of this study is based on conversion of the myoglobin to the selected pigment states, and data in Table 1 indicate that this was achieved. The exteriors of the raw patties were obviously purple-red, bright-red, or brown. The instrumental color readings also clearly indicate different pigment forms. Values for a* and saturation index were highest (most intense red) for patties with OMb, intermediate for DMb, and least red for MMb. Critical also to this study was verifying the pigment state in the patty interior immediately before cooking. Compared to the exterior colors (Table 1), no major changes occurred in the interior pigment prior to cooking due to packaging, freezing, storage, or thawing.

The myoglobin form in the patty interior at the time of cooking had significant effects (Table 2) on visual and instrumental cooked colors. At 55°C, only patties whose pigment was DMb had ($P<.05$) a red, undercooked appearance. Patties that contained OMB or MMb were essentially brown at 55°C and had lower (P<.05) a*, b*, and saturation index values than did patties with DMb. Our data agree with results of Machlik (1965), who reported that MMb denatured at the lowest temperature, OMb at an intermediate temperature, and DMb at the highest.

Patties cooked to 65°C were slightly pink internally if they contained DMb, whereas those containing OMb or MMb appeared brown and more well done. Although patties with DMb had significantly lower visual scores at 75°C than those with OMb or MMb, all patties appeared brown and well done.

As patty endpoint temperature increased, the color indicating apparent doneness of patties changed from red to pink to brown only if the pigment was DMb. Patties with OMb or MMb were brown at 55°C and only became more brown as endpoint temperatures increased. Even at 55°C, patties with OMb or MMb appeared done enough to consume. The only visual clue that these patties were still undercooked was the softer, more moist appearance of their interiors.

Warren (1994) concluded that a reduced pigment was needed to yield a normal cooked color change from red to brown, whereas oxidized pigment resulted in premature browning of patties. Data from the current study indicate a more complicated nature of cooked color, because both DMb and OMb contain ferrous iron in the myoglobin, yet only patties with DMb had a red-pink color at a low (55°C) endpoint.

CONCLUSIONS

The state of myoglobin in the interior of ground beef patties at time of cooking has a major effect on cooked color development. If patties contain predominately MMB or OMb, then a brown, more well-done appearance will develop at endpoint temperatures low enough to permit survival of pathogenic bacteria. Monitoring the endpoint temperature of patties or following a prescribed time X temperature interaction known to achieve a given endpoint are the safest ways to prevent consumption of undercooked ground beef.

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TABLE 1. Color traits of uncooked ground beef patties made to contain deoxy-(DMb), oxy-(OMb), and metmyoglobin (MMb).

Trait	Myoglobin form, fresh patties			Myoglobin form, thawed patties		
	DMb	OMb	MMb	DMb	OMb	MMb
Visual color, exterior	1.2c	3.0b	4.9a	-----	-----	-----
Visual color, interior	-----	-----	-----	1.0c	3.4b	4.9a
L* value	54.2b	53.4b	56.4a	53.7a	55.5a	54.4a
a* value	16.2b	19.2a	8.2c	18.4b	23.6a	10.5c
b* value	8.6c	12.2a	10.4b	10.8c	14.6a	11.3b
Saturation index	18.3b	22.8a	13.2c	21.3b	28.8a	15.4c

[a-c] Means for myoglobin form within fresh and thawed patties with a different letter are different (P<.05).
Visual scoring scale: 1=purple red, 3=bright red, 5=tan or brown.

TABLE 2. Internal color characteristics of ground beef patties containing deoxy-(DMb), oxy-(OMb), or metmyoglobin (MMb) when cooked to 55, 65, or 75°C.

Trait	Endpoint temperature, C								
	55			65			75		
	DMb	OMb	MMb	DMb	OMb	MMb	DMb	OMb	MMb
Visual color, interior	1.3c	4.3b	4.6a	2.8c	4.7b	4.9a	4.6b	5.0a	5.0a
L* value	55.5b	54.3b	55.7a	56.6a	55.7a	56.6a	58.0a	56.5b	57.3ab
a* value	19.0a	11.5b	11.0b	16.2a	9.0b	8.4a	8.5a	7.4b	7.4b
b* value	13.7a	13.0b	12.5b	13.7a	12.5b	11.9b	12.5a	11.5b	11.1b
Saturation index	23.4a	17.3b	16.7b	21.2a	15.3b	14.6b	15.1a	13.7b	13.3b

[a-c] Means for each trait within a temperature with a different letter are different (P<.05).
Visual scoring scale: 1=dark red to purple, 3=very pink, 5=tan,no evidence of pink.