FACTORS AFFECTING PREMATURE BROWNING IN COOKED GROUND BEEF

HUNT M.C., WARREN K.E., KROPF D.H., HAGUE M.A., WALDNER C.L., STRODA S.L., and KASTNER C.L.

Dept. Animal Science, Kansas State Univ., Manhattan, KS, USA

S-VIB.24

SUMMARY

Some ground beef patties develop an internal, brown cooked color and the patty looks well-done at temperatures as low as 55°C. This research examined the etiology of this color pattern as it raises concerns for food safety. Raw patty heme and nonheme iron, myoglobin, and total pigment concentrations did not differ ($P>0.05$) between patties with normal (NOR) and premature brown (PMB) color. At 55°C, PMB patties were brown, whereas NOR patties were red to pink. PMB was not related to % fat, patty compaction, animal source and maturity, or pH (5.5 to 5.8). Since oxidation-reduction potential and total reducing activities were higher ($P<0.05$) and TBA numbers were lower ($P<0.05$) in NOR patties than in PMB, the PMB color appeared related to patty oxidation. When the myoglobin state was modified before cookery, oxidized pigment produced a PMB color, whereas reduced pigment produced NOR cooked color. We conclude that factors affecting muscle reducing ability must be controlled to retain reducing capacity sufficient to develop normal cooked color of ground beef.

INTRODUCTION

Typically, internal color of cooked meat changes from red to pink to tan as endpoint temperatures increase, and these colors are often used to assess degree of doneness. This is a reliable assessment only as long as cooking causes typical cooked meat colors to develop. However, development of a well-done appearance in ground beef at temperatures lower than expected was noted by Marksberry (1990). Since this PMB color could result in consumers eating undercooked ground beef, concerns for food safety were raised.

Marksberry (1990) first thought that PMB was related to E-maturity meat, but Hague et al. (1994) found PMB in patties made from meat from young and old animals and from meat trimmings imported into the USA. Warren (1994) reported that length of frozen storage of patties was not a major factor in development of PMB cooked color. This research examined the chemical properties of ground beef that turned brown prematurely during cooking.

MATERIALS & METHODS

Samples exhibiting NRM and PMB cooked color were obtained from the quadriceps muscle of A- and E-maturity, British-beef and dairy breeds, and from frozen imported beef trimmings. All raw materials had a pH of 5.5 to 5.8, and additional fat had been added to the formulation of some patties (3 to 18% fat). Patties (113g) were formed, crust frozen (-40°C), vacuum packaged, and stored -20°C. Length of frozen storage varied from 2 to 11 mo.

Chemical Traits

Oxidation-reduction potential of raw samples was measured using a pH meter equipped with a platinum redox and a silver/silver chloride reference electrode. TBA values were determined on raw patties using the perchloric acid extraction method of Kuntapanit (1978). Total reducing activity (Lee et al., 1981) was determined on raw samples. Total pigment was determined using the potassium cyanide and potassium ferricyanide procedure. Heme iron was determined using the absorption procedures of Gomez-Basuri and Regenstein (1992). Nonheme iron was determined using methods of Schricker et al. (1982).

Chemical Modification of Pigment State

Patties exhibiting NRM and PMB cooked color received three chemical modifications: 1. no chemical modification (NO); 2. reduced (RD; 10 mL of 0.05mM sodium hydrosulfite); and 3. oxidized (OX; 10 mL of 0.04 mM potassium ferricyanide) for a total of six treatment combinations. Following modification, patties were held at 4°C for 15-30 min to allow sufficient reduction of pigment to the deoxymyoglobin state, but not the subsequent metmyoglobin formation as oxygen migrated into the patty.

Color Evaluation and Cookery

Prior to cooking, external and internal patty color were assessed visually to the nearest half-point using a five point descriptive scale (1=purple red, 2=dark reddish purple, 3=bright red, 4=brownish red, 5=very brown). Patties were cooked to 55, 65, or 75°C on an electric griddle (163°C). Internal temperature was monitored by intermittently inserting a hypodermic thermo-probe into the patty. Patties were cooled five min and sliced horizontally to the patty thickness for internal color evaluation to the nearest half-point using a five-point descriptive scale (1=very dark red to purple, 2=bright red, 3=very pink, 4=slightly pink, 5=tan no evidence of pink). A Hunter Labscan 6000 was used to instrumentally evaluate color for CIE L*a*b* values. Hue angle and saturation index were calculated. Expressible juice was squeezed from patties and its color was evaluated to the nearest half-point using a five-point scale (1=dark, dull red; 2=red; 3=pink; 4=pinkish tan; 5=yellow, no pink). Raw and cooked patties were analyzed for pH, moisture, fat, and protein.

Statistical Analysis

Data were analyzed as a completely randomized design where treatments were a 2 x 3 factorial with cooked color group and either endpoint temperature or chemical modification as variables. SAS General Linear Models procedures and least square means separation techniques were used.

RESULTS & DISCUSSION

Internal cooked color

A significant interaction was found for virtually all cooked color traits. As expected, patties from the NRM group exhibited a typical color change during cooking from red to more tan as endpoint temperature increased. At all three endpoint temperatures, patties that had PMB were described as slightly pink to tan with no evidence of pink color. Visually, at 55°C the NRM group was the most red ($P<0.05$), followed by NRM at 65°C (Table 1). Patties that were NRM at 75°C, PMB at 55°C, and PMB at 65°C did not differ ($P>0.05$). Patties with PMB did not differ visually at 55, 65, or 75°C ($P>0.05$). Instrumental measurements (Table 1) supported visual scores since patties from NRM at 55°C were the reddest (highest a*, lowest hue angle) and most intense in color (saturation index). For most instrumental color traits, the NRM at 65°C group was intermediate in redness ($P<0.05$), and NRM at 75°C and PMB at 55°C were less red and not different ($P>0.05$). For most instrumental traits, PMB at 65°C and PMB at 75°C did not differ ($P>0.05$) and both exhibited the least ($P<0.05$) redness.

Chemical Traits

Patties that had PMB cooked color had higher ($P<0.05$) TBA values (Table 2) than patties with NRM color indicating more oxidative conditions in the PMB group. Lower ($P<0.05$) total reducing activity and oxidative-reductive potentials also were found in patties that had PMB cooked color. No differences ($P>0.05$) for heme, non-heme, or total pigment occurred in raw patties from the two cooked color groups (Table 2). However, numerical differences that would be expected did occur between cooked color groups. After cooking, patties with NRM color at 55°C retained higher concentrations extractable total pigment and heme iron compared to patties with PMB color at 55°C. Nonheme iron increased more in patties with PMB than NRM color upon heating to 55°C. Overall, patties with PMB cooked color were more oxidized and exhibited less reducing ability compared to patties with NRM color, thus indicating a definite difference in the oxidative state between PMB and NRM cooked color groups.

Chemical Modification of Pigment State

Since patties from NRM group had higher total reducing activity than those in the PMB group (Table 2), we examined the effects of modifying the myoglobin state before cooking. Patties with NO and RD modifications did not differ in total reducing activity ($P>0.05$) and both were considerably higher ($P<0.05$) in reducing activity than patties with OX modification (Table 3). The potassium ferricyanide in OX patties may have confounded determination of total reducing activity, since it is the compound monitored for reducing activity. Thus, the extremely low total reducing abilities of OX patties were not unexpected.

Raw External and Internal Modified Colors

Raw patty external and internal appearances were altered by chemical modification (Table 3). Visually, patties from NRM-RD, PMB-RD and NRM-NO groups were the most ($P<0.05$) purplish red. Patties from NRM-OX, PMB-OX, and PMB-NO groups were the most oxidized and brown in appearance. OX modification resulted in patties with a brown external and internal appearance, indicative of a metmyoglobin. RD resulted in a purple-red external surface and purple-red internal surface typical of deoxymyoglobin. Instrumental color (not all data shown in Table 3) followed a pattern similar to visual evaluations with NRM patties having higher ($P<0.05$) a* values and lower ($P<0.05$) hue angles (more red) than PMB patties. RD patties had the highest ($P<0.05$) a* values and saturation indices and the lowest ($P<0.05$) hue angle, NO was intermediate, and those with OX had instrumental values indicative of being brown.

Cooked internal color

Patties with NRM-RD treatment had the most ($P<0.05$) red internal visual cooked color (Table 3). NO-NRM and RD-PMB patties were intermediate and were scored very pink. PMB-NO and -OX modifications yielded patties that were the least red. Instrumentally (not all data shown), patties from NRM-RD and PMB-RD groups had the highest ($P<0.05$) a* values and saturation indices (Table 3). Hue angle did not differ ($P>0.05$) between patties in the NRM-RD, PMB-RD and NRM-NO groups, and all had lower ($P<0.05$) hue angles (more red) than patties from NRM-OX, PMB-OX, and PMB-NO groups. Patties from NRM-NO and NRM-OX groups were darker ($P<0.05$; lower L* values) than those from PMB-NO, PMB-OX, and NRM-RD. Patties that were RD had the most ($P<0.05$) yellow (higher b* values), the NO patties were intermediate, and patties that were OX had the least ($P<0.05$) yellow. These differences in L* and b* values may be related to the overall intensity of color in the patties.

Although differences occurred in the internal patty appearance between cooked color groups and due to the chemical modification, no differences in color of expressible juice were found. The juice from patties from all treatment groups was very red in color. The reason for the disparity in patty color (red vs. brown) and juice color is unknown. Similar results were shown by Hague (1992), in that expressible juice color and internal patty color were not highly related. Endpoint temperature was more related to expressible juice color than internal patty color, especially at low endpoint temperatures.

The relationship between pigment oxidative state and internal cooked color indicates the need for rapid and conscientious handling of raw materials to insure sufficient reductive capacity in meat that will lead to normal cooked color. As oxidized ground beef leads to the development of premature brown internal color, factors influencing metmyoglobin formation may also influence premature browning. Storage temperature and inherent muscle variability are two key factors to consider in color stability. Higher temperatures promote greater oxygen uptake and more rapid utilization of reducing enzymes. Increasing length of time postmortem and mechanical manipulation of muscle, such as grinding, drastically decrease muscle's reducing ability. Although high pH promotes a persistent pink color in ground beef, ultimate pH does not appear related to premature browning (Marksberry, 1990; Hague et al., 1994). However, effects of a rapid pH decline during chilling while carcass temperature is still high, would not be evident with ultimate postmortem pH and might promote premature browning by decreasing myoglobin stability. Fat level, chill rate, length of frozen storage, and type of packaging impact upon the development of rancidity in frozen patties and could increase the likelihood of premature browning.

CONCLUSIONS

Previous studies (Marksberry, 1990; Hague et al., 1994; Warren, 1994) indicate that animal breed-type, physiological age, muscle pH, patty fat level and compaction, and short-term frozen storage do not appear

to be involved, or at least, were not the primary factors, in premature browning in ground beef. This study shows that the oxidative state of the myoglobin at cooking plays a major role in the development of a brown internal color of ground beef cooked to low endpoint temperatures but does not affect the appearance of expressible juice. Therefore, as recommended by Hague (1992), expressible juice color and not internal appearance would be a more reliable visual indicator of patty doneness. It appears that any factor promoting oxidation and decreases in muscle reducing ability will promote conditions that cause premature browning during cooking of ground beef.

REFERENCES

Gomez-Basuri, J.V. and Regenstein, J.M. 1992. Processing and frozen storage effects on the iron content of cod and mackerel. J. Food Sci. 57:1132.

Hague, M.A., Warren, K.E., Hunt, M.C., Kropf, D.H., Kastner, C.L., Stroda, S.L., and Johnson, D.E. 1994. Endpoint temperature, internal cooked color, and expressible juice color relationships in ground beef patties. J. Food Sci. (accepted).

Kuntapanit, C. 1978. Beef muscle and adipose lipid deterioration as affected by nutritional regime, vacuum aging, display and carcass conditioning. Ph.D. thesis. Kansas State Univ. p. 117

Lee, M., Cassens, R.G., and Fennema, O.R. 1981. Effect of metal ions on residual nitrite. J. Food Processing and Preservation. 5:181-205.

Marksberry, C.L. 1990. The effect of fat level, pH, carcass maturity, and compaction on the cooked internal color of ground beef patties at five endpoint temperatures. M.S. Thesis, Kansas State University. Manhattan, KS.

Warren, K.E. 1994. An Investigation of the Chemical Properties Associated with Normal and Premature Brown Cooked Color Development in Ground Beef Patties. Ph.D. Dissertation. Kansas State University. Manhattan, KS.