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DEVELOPMENT OF AN INJECTABLE "MODIFIED MARBLING" SOLUTION FOR WHOLE MUSCLE BEEF CUTS

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Introduction

The amount of marbling or intramuscular fat has been shown to influence the palatability (juiciness, tenderness, flavor) of beef cuts. Tatum et al. (1982) showed that marbling has a low but positive relationship on all beef palatability traits and also found that 90% of the time steaks with Slight or higher degrees of marbling were more desirable in tenderness, flavor and overall palatability. Smith et al. (1984) also reported minute, but statistically significant differences in meat palatability as the degree of marbling decreased from Moderately Abundant (USDA Prime) to Practically Devoid (USDA Standard). Savell and Cross (1988) developed a "window of acceptability" for percent intramuscular fat or marbling of retail beef cuts. Beef cuts containing 3-7% intramuscular fat are perceived by consumers to be acceptable in tenderness, juiciness, flavor and overall palatability so it is important to have at least 3% intramuscular fat in whole muscle beef cuts.

Studies have been conducted to determine quality inconsistencies within the beef industry chain, from farm to retail. The results from the last National Beef Quality Audit (McKenna et al., 2002) indicated that the overall average scores for intramuscular fat or marbling and USDA beef carcass quality grades were below the expectations of the meat industry which can influence the consumer's purchasing decisions. When consumers are not satisfied with the palatability of beef cuts, their intent to purchase beef may decrease and along with it is the opportunity for the beef industry to generate revenue.

The deposition of intramuscular fat or marbling is influenced by many factors such as breed, length of feeding, type of ration fed and management but it has been shown that there is plenty of room for improvement in the amount of marbling or intramuscular fat in whole muscle beef cuts in order to improve the palatability of the final beef product.

The palatability of whole muscle cuts fabricated from lower quality (less than USDA Choice) beef carcasses may be improved through innovative non-meat ingredient and processing technologies. Several different processing technologies have all ready been used to add value to lower quality meat products including whole muscle cuts. The development of a "modified marbling" from selective non-meat ingredients (sodium alginate, iota carrageenan, whey protein isolate and modified food starch) that can mimic the properties of intramuscular fat and can be directly injected into lower quality whole muscle beef cuts may enhance its overall palatability by mimicking the organoleptic properties of fat and having an appearance similar to that of marbling.

Objectives

The overall goal was to develop an injectable “modified marbling” solution using selected non-meat ingredients that can mimic the properties of intramuscular fat and develop a processing system that can incorporate this “modified marbling” into lower quality, less marbled whole muscle beef cuts. To achieve this goal, there were two separate objectives. In the first objective, response surface methodology was utilized to determine the concentration of each ingredient (sodium alginate, iota carrageenan, whey protein isolate and modified food starch) to be used in the development of the “modified marbling” solution. The second objective was conducted to determine the processing system parameters used to inject the solution into whole muscle beef cuts and to verify the properties of the “modified marbling” solution in whole muscle beef cuts. Ribeye rolls were injected with the solution, cut into steaks and the sensory and chemical properties were compared to three separate controls.

Methodology

Experiment 1

Preliminary studies were conducted to determine the selection of ingredients to be used for the “modified marbling” solution and to determine the concentration ranges of the selected ingredients. From the results of the preliminary studies, twenty-five ingredient combinations (ranging from 0.25 to 0.50% addition) were formulated into 500g solutions using a 2^4 central composite design. Solutions were mixed and the properties of the “modified marbling” solution were determined by measuring the solution viscosity (Brookfield viscometer, 30 °C at speed 100) and pH (Accumet pH Meter, at 22 °C) immediately after the solution was manufactured. The solutions were stored for 24 hr at 4 °C to allow the solutions to gel and objective color (Minolta Chromameter, L*a*b*), water holding capacity (centrifugation of 10 g of sample at 4 °C at 40,000 *x g* for 30 min), water holding capacity over time (exposing a 2.54 x 2.54 x 1.27 cm sample on filter paper at 22 °C for 2 h), and gel strength/hardness (TA-HD*i* texture analyzer with an acrylic probe penetrating the gel plug in the geometric center of the sample depressing the gel 2 cm) were determined.

Generated data were analyzed using the Proc GLM procedure of the Statistical Analysis System (SAS User’s Guide) to determine which factors were significant ($P<0.05$) within the total model. Response surface regression (Proc RSREG) equations were run on those factors that were significant ($P<0.05$). Least squares means tables and response surface graphs were generated and prediction equations were used to determine the optimal level of each ingredient.

Experiment 2

The solution was modified by adding beef tallow (3%) in order to minimize the amount of meat pigments absorbed into the meat matrix and beef flavoring (0.25%) was added to increase the intensity of the beef flavor. A continuous, multi-needle injector designed for low pump percentages (5-7%) was used to create the desired “modified marbling” pattern and the optimal injection parameters were determined. It was found that 200, 4mm needles at a belt speed of 39 strokes/min and pump pressure of 4.5 bar was optimal. The solution was manufactured using a Rotostat mixer, injected into USDA Select ribeye rolls (IMPS 112A), tumbled (1 min) and vacuum packaged. The controls, USDA Select, Low and Average Choice ribeye rolls were passed once through the injector without injecting solution to minimize bias when evaluating tenderness. Ribeye rolls were designated to 0, 14, 28, or 42 days of storage (1°C), weighed for ribeye purge and steaks (2.54 cm) were fabricated on each storage day (n=3 steaks). Warner Bratzler shear force, trained sensory evaluation and a 7-day retail shelf life study were conducted on fabricated steaks from each treatment and control after the designated storage period. TBARS values and percent purge were determined on day 0 and 7 and objective and subjective color were determined on days 0, 3, 5, and 7 of the retail shelf-life study.

The experimental design used was a two-way analysis of variance with four combinations, one treated (Injected USDA Select) and three controls (USDA Select Control, USDA Low Choice Control, and USDA Average Choice Control). Difference among attribute means was determined with a predetermined level of significance ($P<0.05$) using Tukey’s Least Significant Difference procedure (SAS user’s guide).

Results & Discussion

Experiment 1

Solution viscosity tended to increase as the concentration of sodium alginate and iota carrageenan increased ($p<0.05$). The pH was not influenced by any specific treatment combination and the L* color values tended to increase as the concentration of sodium alginate increased to a color value comparable to beef fat L* values (77.20 vs 83.58). A sodium alginate, iota carrageenan interaction increased values for water holding capacity ($p<0.01$) and gel firmness ($p<0.05$). Whey protein isolate and modified food starch were not significant for any of the attributes but were kept in the solution at 0.375% since they contributed to the color and water holding capacity of the gel even though they were not significant. Recommended levels of non-meat ingredients from analysis of the solution and gel were 0.4375% sodium alginate and iota carrageenan and 0.375% whey protein isolate and modified food starch.

Experiment 2

The average injection pick-up for the Injected Select was 9.75%, which was higher then the targeted injection pick-up of 5-7%. The Injected Select treatments had a higher ribeye purge (2.80%) ($p<0.05$) than the USDA Average Choice control (1.26%), which would be expected with the amount of solution injected into the ribeye halves. This was also demonstrated in a study by Milligan et al. (1997), where a solution of $CaCl_2$ was injected into USDA Standard beef inside rounds at 5%. They found that the purge loss was significantly greater the $CaCl_2$ injected roasts than for the control roasts.

There were no differences between the injected and control ribeyes for Warner Bratzler shear force, sensory tenderness, juiciness or steak purge. The similar tenderness and juiciness values between injected and non-injected ribeyes may be attributed to the cooking method (clamshell grill) and endpoint temperature (71 °C) used for analysis. A further study with two different cooking methods (clamshell grill and farberware grill) and two different endpoint temperatures (71 °C and 77 °C) were compared. There were not any differences seen between the cooking methods or the endpoint temperatures. The similar tenderness and juiciness values could also be from passing all control ribeye rolls through the injector (single pass without solution) to minimize bias when evaluating tenderness. The injected ribeyes were higher ($p<0.05$) compared to the USDA Select control in beef fat flavor (4.02 vs. 3.31). However, a slight off-flavor was found ($p<0.05$) in the injected ribeye (1.43), which corresponds to the higher TBARS values (0.85) ($p<0.05$), which may be due to the addition of beef tallow without an antioxidant. There were no significant differences in color scores.

Conclusions

The results indicate that more research is needed in this area. The combination of non-meat ingredients in this study was not affective but the amount and type of fat added to the solution may need to be studied to optimize the "modified marbling." Since the sensory panel was able to detect a difference in beef fat flavor after modifications were done to the "modified marbling," the combination of more fat, possibly in a different form could positively affect palatability attributes of whole muscle beef cuts. This study demonstrates that lower quality grades of beef can be improved using this technique.

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