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BLENDED LIPID SOLUTIONS AS A FUNCTIONAL INGREDIENT TO ENHANCE LOW QUALITY BEEF

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Introduction

USDA beef carcass quality grades are based on carcass maturity and the amount of marbling or intramuscular fat present in the exposed surface of the *longissimus dorsi* muscle at the 12^{th}-13^{th} rib interface (USDA-AMS, 1997). Smith et al. (1984) reported minute, but statistically significant differences in meat palatability (juiciness, tenderness, and flavor) as the degree of marbling decreased from Moderately Abundant (USDA Prime) to Practically Devoid (USDA Standard).

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. Development of a blended lipid solution that can be directly injected into lower quality whole muscle beef cuts (USDA Select or lower) may enhance its overall palatability by mimicking the organoleptic properties of fat and have an appearance similar to that of marbling.

Quinlan and Osburn (2004a) determined optimal combinations of non-meat ingredients that resemble the appearance and functional properties of marbling to determine their feasibility in development of an injectable "modified marbling" solution. A solution of calcium alginate, iota carrageenan, whey protein isolate and modified potato starch was deemed feasible. However, the authors noted that gel solution firmness and hydrophobicity must be improved to enhance gel particle definition and minimize the absorption of the meat pigments within the meat matrix.

A subsequent study (Quinlan and Osburn, 2004b) compared the effect of injecting a solution containing sodium alginate (1%), iota carrageenan (0.4375%), whey protein isolate (1.5%) modified food starch (0.375%), beef tallow (3%) and beef flavoring (0.25%) on the quality attributes of USDA Select ribeye rolls. Injected ribeyes were higher ($P<0.05$) compared to the control (USDA Select, no injection) in beef fat flavor. However a slight sensory off-flavor was found ($P<0.05$) in the injected ribeye which corresponded to higher TBARS values ($P<0.05$). The authors concluded that improvements must be made to minimize the off-flavor. Additionally, the evaluated solution continued to hydrate and become more viscous after mixing and during injection, which created problems in attaining the desired targeted percent injection level and obtaining proper dispersion of the solution into the meat matrix.

Blends of fatty acids may be manufactured as a "modified lipid" solution that could be incorporated into meat products to mimic the functional and organoleptic properties of

intramuscular fat (marbling) in whole muscle meat subprimals. As an added benefit, meat products enriched with oleic acid may be legitimately promoted as a functional food.

Objectives

Hypothesis: Development of a blended lipid solution containing beef tallow and safflower oil can mimic the organoleptic properties of intramuscular fat and enhance the quality of lower quality beef subprimals.

Objective: To develop an injectable lipid solution that is similar to intramuscular fat in appearance and functionality, but superior in nutritional quality.

Materials and Methods

Preliminary Study

A preliminary study determined that a blend of 30-60% of beef tallow and 40-70% safflower oil could produce blended lipid solutions that could be pumped through a hand held brine pump at 4.4, 7.2 and 10^{o}C. When injected into boneless beef inside round muscles the injected solution created fat-like particles that looked like marbling. These results indicated that blended lipid solutions could be manufactured with varying solidification points and acceptable viscosity for mechanical injection systems.

Lipid Solution Formulation and Manufacture

Based on the results of the preliminary study, varying percentages of rendered beef tallow (BT, Proliant, Inc, Ames IA) and high oleic safflower oil (HOSO, Montola Growers Inc, Culbertson, MT) were formulated to produce 1000g lipid solutions containing 50/50, 53/47, 57/43 and 60/40 percent of BT and HOSO respectively, and then blended at either 22^{o} or 32^{o}C. Lipid solutions blended at 22^{o}C were formulated by weighing appropriate amounts of refrigerated (7.2^{o}C) BT and HOSO to achieve the desired percentage of each ingredient and placed into 1000 mL beakers, covered with plastic and aluminum foil and tempered at 22^{o}C for 72 h.

Lipid solutions blended at 38^{o}C were formulated as previously described with the exception that the samples were kept in refrigerated storage (7.2^{o}C) for 72 h prior to blending. At Day 0 each BT/HOSO x temperature treatment combination (n=8) was blended in a randomly assigned order. Lipid solutions manufactured at 22^{o}C were blended by pouring the appropriate amount of HOSO into a Waring blender, followed by addition of one-third of the required amount of BT. The lipids were blended for 30 sec. on a high speed setting until all the tallow was thoroughly mixed.

After the initial mixing, the remaining BT was added and the lipid solution mixed an additional 30 sec. In producing the 32^{o}C blended lipid solution treatments, the pre-weighed refrigerated HOSO was poured into a poured into a 2000 mL beaker, placed on a heated stir plate (set on medium heat and medium stirring speed) and heated for 7 min until the oil reached 26^{o}C. One-half of the required BT was then added to the HOSO and the mixture heated to 26^{o}C (13 min). The remaining BT was added and blended an additional 5 min until the solution reached 32^{o}C (25 min total).

Temperature of the lipid solution was continually monitored using a copper constantan thermocouple (Omega Engineering Inc; Stamford, CT). Immediately following mixing of either treatment, the appropriate amounts of each lipid solution blend were weighed into various containers, placed in a refrigerated cooler until the solutions reached 7.2^{o}C and then analyzed for pH, viscosity and fatty acid composition (Day 0) and for color (L*, a* and b*) and thiobarbituric acid reactive substances (TBARS); (Day 0, 3 and 7).

pH

Lipid solution samples (10g) were homogenized using a Polytron homogenizer (Kinematica, Switzerland) with 90 mL of dd H_2O and readings taken using an Accumet pH meter. Readings were measured at 22^{o}C.

Color

A Minolta Colorimeter (CR-300, Minolta Co., Ramsey, NJ) with a 10° standard observer and an 8 mm reading orifice was used to measure the L* (lightness), a* and b* values of the exterior surface color of each lipid solution. On each day of manufacture lipid solution samples (50 g) were placed in petri dishes (n=2) covered with Saran™ wrap and refrigerated (2^{o}C) to allow the solutions to cool and solidify (7^{o}C) before measurements were taken on Day 0. After color measurements were taken, all samples were placed in a retail display case at (2^{o}C; 1200 lx) and color readings taken on Day 3 and 7 of storage.

Viscosity

The viscosity of each lipid solution (50 g) was measured using a Brookfield Viscometer (Model DV-II, Brookfield Engineering, Co., Stoughton, MA) at speed setting 12 and a temperature of (12.7^{o}C). The selected spindle (4) was lowered into the geometric center of the lipid solution until the indented ring on the spindle was level with solution surface. Viscosity readings were recorded in centipoise (cPs) once the displayed reading was stabilized.

Thiobarbituric Acid Reactive Substances Analysis (TBARS)

Thiobarbituric acid reactive substance (TBARS) analysis was conducted on Day 0, 3 and 7 to monitor oxidative rancidity. Four replicates were run for each 30g lipid solution sample according to methods established by Tarladgis and others (1960) and Zipser and others (1962) as modified by Rhee (1978).

Fatty Acid Analyses

The total lipid of each sample was extracted and the fatty acids measured with a Varian gas chromatograph (model CP-3800 fixed with a CP-8200 autosampler (Varian Inc., Walnut Creek, CA). Separation of fatty acid methyl esters was conducted on a silica capillary column CP-Sil88 (Chrompack Inc. Middleburg, The Netherlands) with helium

as the carrier gas (1.2mL/min). After 32 min at 180°C, the oven temperature was increased to 20°C/min to 225°C and held for 13.75 min.

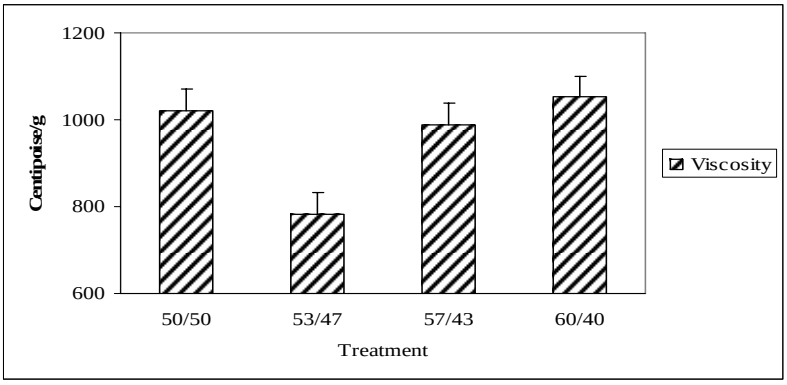
Experimental Design and Statistical Analysis

A two-way analysis of variance with four BT/HOSO combinations and two blending temperatures (n=8) was replicated twice (N=16). For color determinations data was analyzed as a repeated measures design using sample x BT/HOSO x day as the error term. For viscosity measurements, sample temperature was used as a covariate. A predetermined level of significance ($P<0.05$) was used and Tukey's Least Significant Difference determined differences between attribute means (SAS, Version 9.0).

Results and Discussion

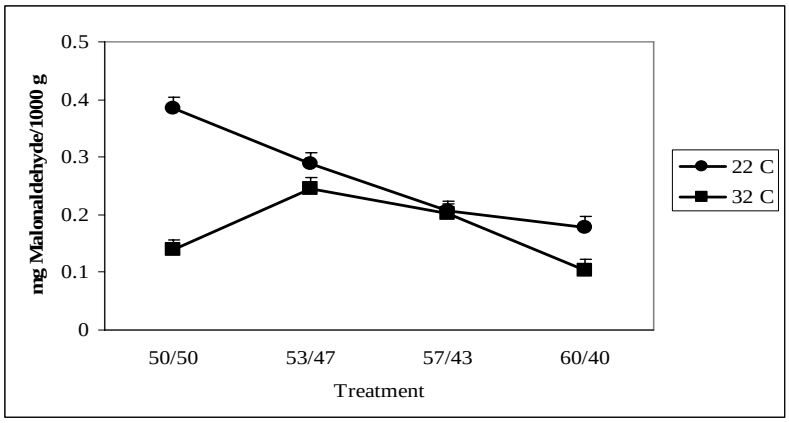
The viscosity of the lipid solution blends were similar among the 50/50, 57/43, and 60/40 BT/HOSO solutions but was considerably lower ($P < 0.01$) for the 53/47 solution (Fig. 1). Temperature at mixing had no effect ($P = .66$) nor did the temperature of the lipid solution blend at the time of measurement affect overall viscosity of the lipid solutions. Solutions blended at 22°C averaged 992.54 cPs/g versus those blended at 32°C which averaged 930.50 cPs/g. Solution temperatures ranged from 12.9 to 14.8°C. As the percent BT increased, the viscosity increased for all solutions with the exception of the 53/47 blend. The decrease in viscosity may be due to differences in mixing (Waring blender for 22°C solutions versus a stir bar for the 32°C solutions).

Figure 1. Least squares means for main effect of percent BT/HOSO ($P<0.05$) on viscosity values



Sample pH values were not different ($P>0.05$) ranging in value from 6.18 to 6.58. A BT/HOSO x day ($P<0.05$) and BT/HOSO x temperature ($P<0.01$) interaction was observed for lipid solution TBARS values. As length of storage increased, TBARS values tended to decrease (Fig. 2a), particularly for solutions containing greater percentages of BT. This same trend was observed with respect to blending temperatures (22 or 32°C; Fig. 2b). The BT contains a higher percentage of saturated fatty acids and is less susceptible to lipid oxidation.

Figure 2b. Least squares means of percent BT/HOSO x temperature interaction for TBAR values among lipid solutions



Lipid solution L* values (Fig. 3a and 3b) showed a BT/HOSO x day ($P<0.05$) and temperature x day interaction ($P<0.01$) was observed. As length of storage increased, L* values tended to increase. Solutions blended at 22°C tended to have constant L* values throughout the 7 day storage period while solutions blended at 32°C exhibited lower L* values on Day 0 but exhibited an increase in L* values throughout storage. This could be attributed to the yellow color observed when beef tallow and safflower oil were heated during blending while solutions blended at 22°C remained white in color. The a* and b* mean values for all lipid solutions were affected by a temperature x day interaction ($P<0.05$). The solution a* values ranged from -5.10 to -2.36 while the b* values ranged from 4.26 to 9.82.

Figure 3a. Least squares means of BT/HOSO x day for L* values of lipid solutions

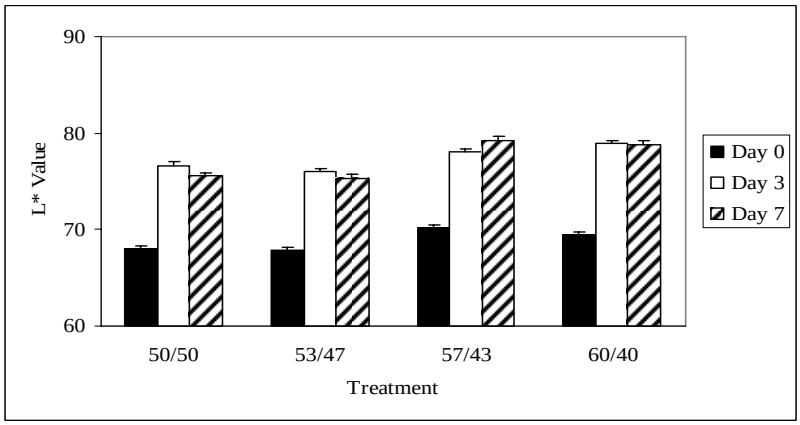
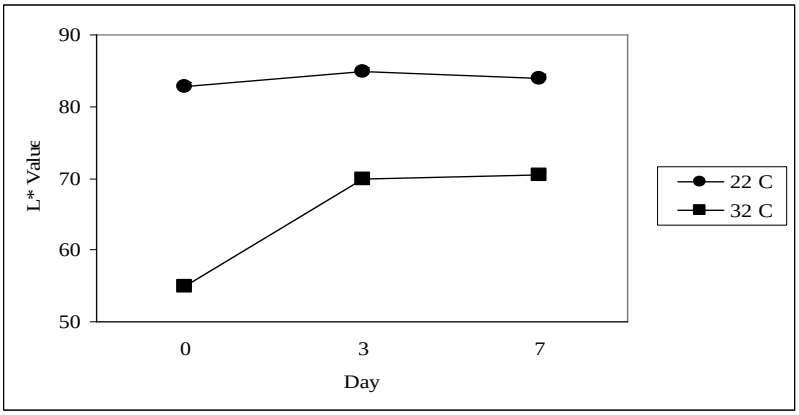


Figure 3b. Least squares means of temperature x day interaction for L* values among lipid solutions



The fatty acid composition of BT, HOSO and lipid solutions are shown in Table 1. Additionally intramuscular fat (marbling) from Angus based cattle fed a commercial corn-fed diet was analyzed. As the percent of BT increased the amount of stearic acid (18:0) increased, while the amount of oleic acid (18:1) and linoleic acid (18:2) decreased. However, when compared to intramuscular fat, although not statistically analyzed, the lipid solutions were much higher in oleic and linoleic acid and lower in stearic acid. Additionally the ratio of saturated to unsaturated fatty acids tended to increase as the amount of BT increased, but was at least 2.5 times lower compared to intramuscular fat. These results indicate that the blended lipid solutions manufactured in this study may be a healthy and nutritious "marbling substitute" if injected into less marbled whole muscle beef subprimals.

Table 1. Least squares means for fatty acid composition among lipid solutions

	Lipid Solutions[d]						
Item	BT	HOSO	50/50	53/47	57/43	60/40	IM[e]
14:0	2.20	0.63	1.16c	1.25b	1.34a	1.40a	3.50
16:0	23.1	3.90	13.8c	14.6bc	15.1ba	15.8a	29.3
16:1	2.30	0.25	1.32c	1.37c	1.46b	1.56a	2.91
18:0	17.5	1.45	9.07b	9.45ba	10.1ba	10.4a	21.7
18:1	38.2	70.5	61.5a	60.9ba	58.6ba	57.9b	38.1
18:2	2.20	12.6	8.63a	8.38ba	7.79bc	7.54c	2.90
Ratio[f]	1.00	0.07	0.34c	0.36bc	0.39ba	0.41a	1.33

[abc]Least square means without common superscript differ (P<0.02)
[d]Lipid Solutions = blends (%) of beef tallow/safflower oil
[e]IM = average composition of dissected intramuscular fat (marbling) from two Angus steers fed a corn-based diet
[f]Ratio = saturated vs. unsaturated fatty acids

Conclusions

This study investigated the feasibility of developing an injectable lipid solution that is similar to intramuscular fat in appearance and functionality, but superior in nutritional quality. We conclude that a blend of BT and HOSO may possess the desired functional (viscosity, color) and nutritional (high oleic acid content, low saturated to unsaturated

fatty acid ratio) attributes to improve the quality of lower marbled beef cuts. Further studies will determine if these solutions can be injected into beef subprimals via an automatic injection system to create fat particles resembling marbling when fabricated into steaks.

References

Quinlan, C.S. and Osburn, W.N. 2004a. Development of "modified marbling" for whole muscle beef cuts. Presented at the 2004 IFT Annual Meeting, Las Vegas, NV.

Quinlan, C.S. and Osburn, W.N. 2004b. Comparison of quality attributes of an injectable "modified marbling" solution to beef fat marbling in whole muscle beef cuts. Submitted (1 Dec 04) for presentation at the 2005 IFT Annual Meeting, Orlando, FL.

Rhee, K. S. 1878. Minimization of further lipid peroxidation in the distillation 2-thiobarbutiric acid test of fish and meat. J. Food Sci. 43: 1776–1778.

Smith, G. C., Carpenter, Z. L., Cross, G. R., Murphey, C. E., Abraham, H. C., Savell, J. W., Davis, G. W., Berry, B. W. and Parrish, F. C., Jr. 1984. Relationship of USDA marbling groups to palatability of cooked beef. J. Food Qual. 7: 289.

Tarladigis, G. G., Wats, B. M., Younthan, M. T. and Dugan, L., Jr. 1960. Distillation method for the quantitative determination of malonaldehyde in rancid foods. J. Am. Oil Chem. Soc. 37: 44–48.

USDA. 1997. Official United States Standards for Grades of Carcass Beef. Agricultural Marketing Service, USDA, Washington, DC.

Zipser, M. W. and Watts, B. M. 1962. Lipid oxidation (TBA) methods. Food Technol. 16: 102.