REDUCTION OF BACTERIAL POPULATIONS BY SURFACE FLAMING IN BEEF TRIM UTILIZED FOR GROUND BEEF PATTIES IN FOOD SERVICE OPERATIONS

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ABSTRACT

Semitendinosus muscles from low quality, cull cows were trimmed, separated into three fat levels (10, 20, and 30%), treated with 0, 5, 10, 15, or 20 seconds of surface flame application, ground, and formed into patties. Patties were quick frozen (-80 C for 1 hr) and stored at -10 C for 0, 4 or 24 days. Hunter "L" and "b" values increased ($P<.01$) and Hunter "a" values decreased ($P<.01$) as flame time increased. Metmyoglobin and discoloration percentages increased ($P<.05$) as flame time increased. High fat patties (30%) had lower cook losses ($P<.01$) as flame time increased due to initial fat loss whereas low fat patties (10%) had constant cook losses. Water-holding-capacity increased ($P<.05$) at extreme flame time (20 secs) in all patties. Juiciness and tenderness scores were significantly decreased and flavor intensity increased in lean patties as flame time increased. Juiciness and tenderness scores in high fat patties were not affected but patties had lower cohesive scores as flame time increased. Aerobic, anaerobic, lactic acid producing, and psychrotrophic bacteria, within each fat level, decreased as flame time increased from 0 to 10, 15, or 20 secs. Temperature abused patties had significantly higher ($P<.01$) bacterial populations than original populations of control patties at each fat level. These data indicate surface flaming initially reduces bacterial populations and minimizes bacterial growth without adverse physical damage to the product. Unfortunately, this method of bacterial reduction is not as effective in patties which are temperature abused.

Key words: beef, bacteria, heat, temperature

INTRODUCTION

Bacteria, including those which can cause foodborne illnesses, are found naturally all around us and rely on nutrients such as those found in most foods to provide energy for their growth and survival. Foodborne illnesses can arise when pathogenic bacteria enter the body through the ingestion of food. Although foodborne illnesses have been traced to many types of foods, the more common carriers of foodborne pathogens are foods of animal origin. As much as 97% of foodborne illnesses are caused by mishandling at home or food service establishments (Bryan, 1982). However, if those products were not initially contaminated, bad handling practices would not create a hazard (Bjerklie and Stentz, 1996).

Pathogens known to be transmitted by muscle foods include Escherichia coli, Salmonella, and Staphylococcus. Of these, E. Coli O157:H7 has emerged as the most noted due to it's extreme virulence and highly publicized outbreaks. In addition to the public health significance of foodborne disease, huge monetary losses are incurred when foods are linked to human illness. In 1992, it was estimated E. coli O157:H7 accounted for 7,668-20,448 of the cases of foodborne illnesses with an average cost of $3,360 per case (Anonymous, 1995). Given the importance of meat-borne bacteria to the overall quality and safety of meat products, methods which eliminate or reduce bacteria, including pathogens such as E. coli O157:H7, are of vital importance to the meat industry (Anonymous, 1994). Research in the production of ground beef, which accounts for nearly half of the beef consumed in the United States, must be targeted to allow processors to identify and utilize resources that currently exist within their facilities. Ideally any method should economically reduce microbial loads while not physically degrading the product. The

experiments in this study were designed to evaluate the capability of producing ground beef with lower microbial levels while causing little or no physical damage to the product at very little added expense.

METHODS AND MATERIALS

Overall Processing Procedure

Semitendinosus muscles from low quality, cull cows (comparable to USDA Utility) were obtained from a local beef processor, vacuum sealed and transported to the Auburn University Lambert Meat Science Laboratory. Each muscle was appropriately trimmed and separated into three fat levels (10, 20, and 30%). Additional fat was added if necessary to achieve the appropriate fat level. Upon separation into fat treatments, the muscles were sliced into 1.27cm^2 strips, with the length of the strips determined by the width of the muscle. Equipment surfaces were sanitized using a dilute ethanol solution (70% v/v). Beef strips were weighed and equal amounts of each fat level were randomly assigned to one of five flame treatments (0, 5, 10, 15, 20 sec) and placed on a stainless steel mesh belt, which allowed for simultaneous thermal treatment of beef strips at a distance of 6.35 cm between the meat and the flame heat source both dorsally and ventrally.

Immediately after flame treatment, beef strips ground twice through a .32 cm grinding plate using a counter top grinder (Kitchen Aid Model #KSM90WH, St. Joseph, MO) and formed with a conventional hand pattie press into approximately 100 g patties. Patties were transferred onto stainless steel trays, quick frozen within 1 hr at -80 C and stored at -10 C until

further analysis at appropriate time periods. Storage periods consisted of 0, 4, and 24 days, respectively. At day 4 of storage a second set of samples was allowed to thaw at room temperature (~ 25 C) for approximately 6 hours to simulate possible temperature abuse and analyzed for microbial attributes.

pH Determination

Product pH was determined using 10 g of sample from each treatment group at the appropriate storage period that was mixed with 99 ml of deionized distilled water. The meat and water were mixed for approximately 30 seconds using a homogenizer (Pro 250 Homogenizer, Monroe, CT) and a pH meter (Extech Instruments Corporation, Waltham, MA) was used to determine the final product pH.

Percent Metmyoglobin

Metmyoglobin concentration was determined in triplicate at each storage period using the methods of Chen and Trout (1991). A 5 g sample was added to 50 ml of a 0.04M phosphate buffer (pH 6.8) and homogenized for 30 sec using a Pro250 Homogenizer (Monroe, CT). The homogenized sample was centrifuged for 30 min at 5 C (50,000 x g). The supernatant was filtered through Whatman No. 1 filter paper and analyzed with a spectrophotometer (Perkin-Elmer model #C688-0000

Lambda 4 UV/VIS). The measurement of metmyoglobin was calculated using the following formula (Kryzwicki, 1979):

Metmyoglobin % = (1.395 - ((572A - (730A*1.45))/(525A - (730A*1.73)))) x 100

Hunter Color and Visual Evaluation

Objective product color was determined using three samples at each storage period by a Hunter Lab Color Difference meter (Hunter Labs D25 DP9000, Reston, VA). Values were obtained and recorded as Hunter color "L", "a", and "b" units. The color meter was allowed to warm up for 15 minutes and calibrated using both white and black tiles.

A visual color evaluation was also conducted by a three member experienced panel. The panelist evaluated patties under normal retail lighting conditions prior to cooking to determine percent surface discoloration.

Water Holding Capacity

Water holding capacity was determined in triplicate for each treatment pattie according to the procedure of Hamm (1960) using a Carver Lab Press. The amount of free water was determined using the following formula:

mg free water = (area in cm^2/ 0.0948) + 8.0

Lipid Oxidation

Triplicate samples were used for the analysis of 2-thiobarbituric acid reactive substances (TBARS) according to procedures described by Ke et al. (1984).

Compositional Analysis

Percent moisture, fat, and protein was determined in triplicates according to methods described by AOAC (1990). Randomly selected samples were taken from the three fat levels of

beef strips immediately after flame treatment.

Microbiological Evaluation

Aerobic-plate counts, psychrotrophic-plate counts, anaerobic-plate counts and lactobacilli-plate counts were determined at each storage period. At each sampling time, meat patties were removed from storage, thawed, and two 11 g samples were aseptically obtained from the centers of each pattie and placed into sterile plastic bags with 99 ml of Butterfield's phosphate buffer. Each sample was homogenized in a stomacher (Model 400 Stomacher, Tekmar Company, Cincinnati, OH) for two minutes, serially diluted with Butterfield's phosphate buffer and spiral plated (Model Du2 Spiral Plater, Spiral Systems, Besthesda, MD). Aerobic-plate counts (APC) and anaerobic-plate-counts were enumerated on plate count agar (PCA; Difco Laboratories, Detroit, MI) and incubated at 37 C for 24 hrs. Psychrotrophic-plate counts were determined on plate count agar incubated at 10 C for 7 days. Lactobacillus-plate counts were determined on MRSA (Lactobacilli de Man Rogosa Sharpe Agar, Difco Laboratories, Detroit, MI) broth with 2% added BactoAgar (Difco Laboratories, Detroit, MI) with plates incubated at 37 C for 24 hrs. After incubation, plates were counted with a laser bacteria colony counter (Model 500A, Spiral Systems Instruments, Bethesda, MD). Microbial data were expressed in $\log_{10}$ cfu/g of sample.

Statistical Analysis

This experiment was conducted as a 3x5 factorial arrangement in a split plot design with three replications per treatment. Fresh beef trim (semitendinosus) of 10, 20, and 30% fat was

randomly assigned to one of five flame treatments (0, 5, 10, 15, and 20 seconds). Storage periods utilized were 0, 4, and 24 days. Treatment means were separated by Student-Newman-Kuels (SNK) after analysis by the GLM procedure (SAS Institute, 1988). When an interaction occurred between treatments, subclass means were separated by the Pdiff test (Steele and Torrie, 1982).

RESULTS AND DISCUSSIONS

Sensory Evaluation

There was no significant interaction ($P<.05$) between treatment and storage time for sensory attributes (Table 1). There were significant differences ($P<.01$) in juiciness, tenderness, off flavor, and cohesiveness between storage times. Flavor intensity was the only attribute which was not significantly different ($P<.05$) between storage time. Significant interaction differences were found for juiciness ($P<.01$), tenderness, off flavor, and cohesiveness scores ($P<.05$) between fat level and flame time. Juiciness scores were significantly higher in low fat patties at 0 flame versus patties at all other flame times which were not different ($P<.05$). As expected, patties with increased fat levels showed no differences between flame times (5.2- 5.6) except 20% fat patties treated for 15 secs which were significantly lower (4.9). Day 24 patties were significantly less juicy than patties at day 0 and 4. Tenderness was not affected at different flame times in 20 and 30% fat patties. However, lean patties (10%) showed decreased tenderness scores in higher flame patties with 10, 15, and 20 secs patties not being different. At day 0 storage, patties were significantly more tender than day 4 and 24. Off flavor was not different at

extreme flame times compared to control patties. There were no significant differences ($P<.05$) between flame times within 20 and 30% fat patties. In low fat patties, day 24 products had significantly higher off flavor scores than day 0 and 4 products. Flavor intensity scores were only significant ($P<.05$) between fat levels. Lean patties (10%) were significantly more intense in flavor than 20 and 30% fat patties due to a greater protein content. Cohesiveness scores had a significant ($P<.05$) interaction between fat level and flame time in 20 and 30% fat patties. Control patties were extremely more cohesive than all other flame times. Five, 10, 15, and 20 secs flame time patties were not significantly different in high fat patties for cohesiveness scores. Low fat patties were not different in cohesiveness scores except with extreme flame times (20 secs). All patties were more cohesive at day 4 and 24 storage than at day 0 storage time. Therefore, these data indicates lean patties are significantly affected by increased flame time. Juiciness and tenderness were greatly decreased by heat application in lean patties while flavor intensity was increased possibly due to product concentration due to moisture loss. Cohesiveness was the only factor not affected until extreme flame treatment (20 secs) in low fat patties. However, higher fat patties were not significantly different in juiciness and tenderness but were less cohesive as flame time increased. Over storage time, all patties were significantly less juicy at day 24 and less tender at day 4 and 24. Low fat patties were higher in off flavor at day 24. Mikel et al. (1996) also found no sensory differences in ground beef patties made from trim treated with low levels of organic acids.

Visual Characteristics

Hunter “L” values (lightness) were different over storage times ($P<.05$), fat levels and

flame treatments (P<.01) as shown in Table 2. As expected, 0 flame time patties displayed the lowest (P<.01) Hunter "L" values with values increasing as flame time increased. Hunter "L" values were highest (P<.01) but not different (P<.05) between patties flamed for 10, 15, and 20 secs. Furthermore, patties of 20 and 30% fat levels were significantly (P<.01) different over time as increased fat content increased Hunter "L" values. At 10% fat there were no differences between day 0, 4, and 24. Also, 30% fat patties were significantly lower at day 0 than day 4 and 24.

Hunter "a" values (redness) decreased (P<.01) as flame time increased within fat levels. Patties with 10% fat, at 0 and 5 secs flame were similar (P<.05) with all other patties significantly different. Patties with 30% fat were significantly (P<.01) different at 0, 5 and 10 secs but similar (P<.05) at 15 and 20. Lastly, 20% fat patties showed significantly higher Hunter "a" values at 0 and 5 secs of flame. Significant differences for Hunter "a" values were found at 0 days of storage time for 10 and 20% fat patties with 4 and 24 day patties not significantly different. However, higher fat patties (30%) were not different until 24 days of storage. Therefore, lower fat patties were effected at shorter storage times. Hunter "b" values (yellowness) generally increased as flame time increased within each fat level indicating flame treatment increased browning both the protein and fat in the product. These results agree with Vosen et al. (1995), who found little effect of flame on product appearance at short application intervals.

Metmyoglobin content showed similar patterns in 10 and 20% fat patties over flame time (Table 2). In 10% fat patties 0, 5, and 10 secs flame treated patties were not different (P<.05). However, patties at increased flame times of 15 and 20 secs were significantly different from 0,

5, and 10 secs patties containing 10 and 20% fat. As expected, metmyoglobin percentage increased within fat levels as flame time increased. High fat patties treated with 20 secs flame had higher concentrations ($P<.05$) than patties flamed for 0, 5, 10, and 15 secs. In low fat patties (10%) 10 secs flamed patties were not significantly different than control patties. Storage time also effected metmyoglobin percentage. At day 24, 30% fat patties had significantly lower metmyoglobin contents than 10 and 20% fat patties. Low fat patties (10%) at day 4 and 24 were significantly higher in metmyoglobin than patties at day 0. These data agree with Vosen et al. (1995) that as storage time increases, higher fat patties have greater metmyoglobin development than low fat patties. Subjective discoloration scores followed similar findings as metmyoglobin content and increased proportionally with flame time similar to those findings of Vosen et al. (1995). At similar flame times, patties of each fat level showed similar discoloration patterns. Furthermore, within fat levels, as flame increased there were significant differences ($P<.05$). High fat patties had higher discoloration scores at 0, 5 flame whereas 10 and 20% fat patties were effected more at higher flame times of 15 and 20 secs. Therefore, discoloration within fat level is effected more by increased flame time. Storage time also effected discoloration of each fat level. Low fat patties (10%) were significantly lower in discoloration scores at day 0 than 4 but not at day 24. Twenty percent fat patties were significantly higher in discoloration at day 24. High fat patties (30%) were significantly ($P<.01$) different in discoloration scores between each storage period with day 0 having lowest and day 24 highest discoloration. This confirms an increase in fat content will increase discoloration of patties over storage time. Reynolds and Carpenter (1974) reported that the use of a high molar concentration of organic acids also discolored pork carcasses. These data also agree with Mikel et al. (1996) who found increased

product discoloration in patties made from 4% organic acid treated trim.

Cook loss is important in controlling final yield of a product. Cook loss is shown in Table 3. Low fat patties (10%) maintained similar cook losses at each flame time. These results are expected since less fat would be lost due to heat application during cooking. In 20% fat patties, there were no differences between 0 and 5 secs flaming time with 10, 15, and 20 secs flamed patties having less cook loss than 0 and 5 secs flamed patties. This significant decrease in cook loss as flame time increases is due to fat loss during flame treatment. High fat patties had less cook loss ($P<.05$) at day 24 but were not different at 0 and 4 days of storage. Therefore, high fat patties (30%) tend to lose more weight due to an increase in flame time and subsequent loss of fat and moisture.

Water-holding-capacity was significantly higher at 20 secs flame ($P<.05$) while all other flame times were not different ($P<.05$). Low fat patties maintained the highest ($P<.05$) water-holding-capacity. This effect was probably due to an accumulation of free water because of decreased fat. Storage periods had no effect ($P<.05$) in low fat patties while in 20% patties day 4 and 24 had higher water-holding-capacities than day 0. Also, in high fat patties water-holding-capacity increased as storage time increased.

There were differences ($P<.05$) in pH over storage time (Table 3). Final product pH at day 0 was significantly higher than at day 4 and 24 within each fat level. Vosen et al. (1995) reported a reduction in product pH of 5.57 at day 0 to 5.53 at day 4 in lean beef patties. One reason for this decrease in pH could be an increase in lactic-acid-producing bacteria over storage time.

Lipid oxidation was analyzed as accumulation of 2-thiobarbituric acid reactive substances method. Results concluded a significant difference between control patties and all flamed patties. TBAR values over storage were higher at day 0 (.7186) and 24 (.7035) than day 4 (.5370) in low fat patties. This disputes Vosen et al. (1995) findings in which there were steady increases in TBARs as storage time increased. There were no significant differences in high fat patties (30%).

Bacterial Characteristics

The primary purpose of using surface flaming on beef trim utilized for ground beef patties was to decrease bacterial populations and proliferation. Hanna et al. (1983) used flame as a method of sterilization. If populations can be decreased, then shelf-life increases as well as possible elimination of any pathogenic bacterial present.

Aerobic, anaerobic, lactic acid producing and psychrotrophic bacterial populations within each fat level decreased as flame time increased (Table 4). Colonies were higher in patties prior to treatment ($P<.01$) than in patties flamed for twenty seconds. There were significant treatment by fat interactions for aerobic ($P<.05$), anaerobic and psychrotrophic ($P<.01$) bacteria. Furthermore, there were significant day-by-fat interactions for anaerobic and psychrotrophic ($P<.05$) and treatment-by-day interaction for lactic acid producing and psychrotrophic ($P<.05$) bacteria (Table 1). Initial bacterial populations were highest in 20 percent beef patties. Aerobic-plate-counts were different ($P<.01$) among flamed patties as compared to patties not flamed. After 5 seconds of flame treatment, aerobic populations decreased from 4.05 log CFU/g at 0 flame time to 3.53 log CFU/g. Further decreases occurred upon flame time increased to 10,

15, or 20, in 10% fat patties. Storage time appeared to have little effect on the increased aerobic plate counts. However, there was a significant difference at day 4pm (Table 4) than other storage days when frozen product was analyzed. Aerobic, anaerobic, lactic-acid producing and psychrotrophs increased to higher than the original bacterial populations of controls. In fact, patties exposed to 20 seconds of flame had aerobic-plate-count increases of 2.46 log CFU/g at day 0 to 3.57 at day 4 pm. It may be concluded that exposing patties to an abusive environment over time increases bacterial counts as expected.

Anaerobic bacteria were significantly ($P<.01$) decreased within all fat levels at 5 secs of flame treatment. After 5 secs of flame there was a .6 Log CFU/g reduction in both 10 and 30% fat patties while there was more than a 1 Log CFU/g reduction in 20% fat patties. However, in 20% fat patties there was a 1.9 log CFU/g reduction at 10 secs flame. This may conclude anaerobes can be greatly reduced with minimal heat treatment. There were no differences over frozen storage times in 20 and 30% fat patties. However, abused patties at day 4 p.m. displayed higher anaerobic plate counts than the control patties at day 0.

Lactobacillus plate counts decreased as flame time increased at day 0. At day 4, 10 secs flame significantly decreased counts by over 1.5 log CFU/g. At day 24 there were no differences between 10, 15, and 20 secs flame. The abused patties (4pm) again were higher in all treatments than patties not flamed.

Psychrotrophic plate counts showed minimal changes over storage periods except in abused patties at day 4 pm. Psychrotrophs followed a similar pattern as Lactobacillus populations. A treatment of 10 secs significantly decreased bacterial counts. At day 4 p.m. counts were elevated to above the level of control patties at day 0. In conclusion, surface

flaming initially destroys many bacterial populations. Vosen et al. (1995) flame used in low fat patties were not effective in decreasing microbial populations but was in high fat patties. However, if patties are temperature abused more than 6 hours, there was an actual increase in bacterial populations. Analysis revealed that flaming patties does minimize bacterial growth and proliferation if patties are not temperature abused.

CONCLUSIONS

In conclusion, flame treatments greatly decreased juiciness and tenderness in lean patties while not negatively affecting high fat patties as flame time increased except for decreased cohesiveness scores. Evidently, flame treatment of high fat patties was not of duration to affect protein integrity. Hunter "a" values decreased and Hunter "L" and "b" values increased as flame time increased. Metmyoglobin concentration and percent discoloration also increased proportionally as flame time increased indicating increased surface browning of product proteins and fat. However, co-mingling of trim pieces during grinding decreased negative effects on visual acceptance. In high fat patties, cook loss was reduced as flame time increased due to the initial loss of fat and moisture during flaming.

Aerobic, anaerobic, lactic acid producing, and psychrotrophic bacteria populations within each fat level decreased as flame time increased. However, as products were temperature abused at day 4, all bacterial populations increased indicating this method is successful in controlling bacterial populations only if product temperature as well good manufacturing practices are well maintained.

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TABLE 1. Sensory evaluation of three fat levels of ground beef patties over storage time as affected by surface flaming.

FACTOR		Juice[k]	Tender[k]	Off Flavor[k]	Flav Int[k]	Cohes[k]
Day		**[m]	**	**	NS[m]	**
Trt[l]		*[m]	NS	NS	NS	**
Fat[l]		**	**	NS	*	**
Day x Trt[l]		NS	NS	NS	NS	NS
Fat x Trt[l]		**	*	*	NS	*
10	0	4.8[c]	5.6[b]	5.9[bc]	5.8[a]	5.8[a]
20	0	5.5[a]	6.5[a]	6.5[a]	5.5[a]	4.8[b]
30	0	5.2[ab]	6.5[a]	6.1[ab]	5.6[a]	5.0[b]
10	5	4.0[d]	5.5[bc]	6.3[ab]	5.8[a]	5.5[ab]
20	5	5.3[ab]	6.6[a]	6.4[ab]	5.3[a]	4.4[c]
30	5	5.6[a]	6.6[a]	6.3[ab]	5.3[a]	3.8[de]
10	10	3.8[d]	5.1[cd]	6.5[a]	5.7[a]	5.7[a]
20	10	5.4[a]	6.6[a]	6.1[ab]	5.5[a]	4.1[cd]
30	10	5.5[a]	6.7[a]	6.4[ab]	5.4[a]	3.6[de]
10	15	3.9[d]	5.2[cd]	6.1[ab]	5.6[a]	5.4[ab]
20	15	4.9[bc]	6.4[a]	6.3[ab]	5.3[a]	4.0[cd]
30	15	5.6[a]	6.7[a]	6.1[ab]	5.6[a]	3.5[e]
10	20	3.6[d]	5.1[d]	5.5[c]	5.6[a]	5.2[b]
20	20	5.4[a]	6.7[a]	6.2[ab]	5.6[a]	4.1[cd]
30	20	5.4[a]	6.4[a]	6.3[ab]	5.5[a]	3.5[e]
	SEM[n]	.1631	.1307	.1847	.1338	.1586
Fat x Day		NS	NS	**	NS	**
10	0	4.4[a]	5.4[a]	6.6[a]	5.6	5.2[b]
10	4	4.2[a]	5.3[b]	6.3[ab]	5.8	5.8[a]
10	24	3.4[b]	5.2[b]	5.4[c]	5.7	5.6[a]
20	0	5.6[a]	6.9[a]	6.2[ab]	5.4	3.7[de]
20	4	5.3[a]	6.5[b]	6.7[a]	5.6	4.8[b]
20	24	4.9[b]	6.3[b]	6.0[b]	5.4	4.3[c]
30	0	5.7[a]	6.8[a]	6.7[a]	5.6	3.4[e]
30	4	5.7[a]	6.5[b]	5.9[b]	5.4	3.9[d]
30	24	5.1[b]	6.5[b]	6.1[b]	5.5	4.3[c]
	SEM[n]	.1264	.1013	.1431	.1036	.1586

[abcdefghij] Means within columns with uncommon superscripts are significantly different.

[k] Juiciness, Tenderness, Off Flavor, Flavor Intensity, and Cohesiveness scores (8=extremely juicy, tender, intense and cohesive and no off flavor;1=extremely dry, tough, bland, non-cohesive and strong off flavor).

[l] TRT = time in seconds of surface flame application. Fat = expressed as %.

[m] NS = not significant; * = $P<0.05$; ** = $P<0.01$.

[n] SEM = standard error of the means.

TABLE 2. Visual characteristics of three fat levels of ground beef patties over storage time as affected by surface flaming.

FACTOR		Hunter L	Hunter a	Hunter b	Metmyo[h]	Discolor[h]
Day		*[j]	**[j]	**	**	**
Fat[i]		**	**	**	**	**
Trt[i]		**	**	**	**	**
Day x	Trt[i]	NS	NS	NS	NS	NS
Fat x	Trt[i]	NS[j]	**	**	*	*
10	0	35.9	12.8^{c}	8.4^{g}	27.8^{bcd}	8.1^{j}
20	0	45.7	18.0^{a}	12.6^{ab}	25.5^{de}	7.9^{j}
30	0	45.6	15.7^{b}	13.1^{b}	21.7^{e}	14.1^{ij}
10	5	37.2	13.0^{c}	9.8^{ef}	28.1^{bcd}	20.0^{hi}
20	5	46.3	15.0^{b}	12.6^{ab}	32.3^{b}	21.6^{hi}
30	5	48.1	12.6^{cd}	12.1^{bc}	22.9^{c}	26.9^{h}
10	10	40.2	11.8^{d}	9.9^{ef}	32.9^{b}	35.0^{g}
20	10	47.2	12.2^{cd}	10.9^{de}	31.3^{bc}	35.9^{fg}
30	10	50.0	10.7^{e}	11.9^{bc}	25.2^{de}	43.1^{f}
10	15	40.7	10.1^{e}	9.4^{f}	37.5^{a}	55.6^{e}
20	15	46.3	10.8^{e}	10.8^{de}	38.9^{a}	68.1^{cd}
30	15	50.6	9.1^{f}	10.5^{de}	27.5^{bcd}	64.6^{d}
10	20	40.4	9.1^{f}	9.6^{f}	39.8^{a}	72.3^{bc}
20	20	46.0	9.1^{f}	10.2^{ef}	40.4^{a}	85.0^{a}
30	20	48.3	8.8^{f}	11.3^{cd}	39.9^{a}	77.6^{ab}
	SEM[k]	.8394	.3508	.3170	1.6085	2.673
Fat x	Day	*	**	**	**	**
10	0	38.4^{e}	13.3^{ab}	10.4^{d}	29.1^{de}	34.0^{f}
10	4	39.4^{e}	10.5^{d}	9.0^{e}	34.6^{bc}	42.1^{cd}
10	24	38.8^{e}	10.3^{d}	8.8^{e}	36.0^{ab}	38.8^{def}
20	0	45.3^{d}	13.9^{a}	11.3^{bc}	30.6^{d}	40.8^{cde}
20	4	47.8^{bc}	12.4^{c}	10.9^{cd}	38.7^{a}	41.0^{cde}
20	24	45.8^{d}	12.8^{bc}	11.9^{ab}	31.8^{cd}	49.3^{b}
30	0	46.4^{cd}	12.5^{c}	12.4^{a}	25.9^{e}	35.2^{ef}
30	4	48.6^{ab}	12.6^{bc}	12.3^{a}	30.4^{d}	45.2^{bc}
30	24	50.2^{a}	9.0^{e}	10.6^{d}	26.1^{e}	55.4^{a}
	SEM[k]	.6502	.2717	.2458	1.2460	2.079

[abcdefg] Means within columns with different superscripts are significantly different.

[h] Metmyoglobin and Discoloration expressed as %.

TRT = time in seconds of surface flame application. Fat = expressed as %.

[i] NS = not significant; * = P<0.05; ** = P<0.01.

[k] SEM = standard error of the means.

TABLE 3. Physical characteristics of three fat levels of ground beef patties over storage time as affected by surface flaming.

FACTOR		Cook Loss[i]	WHC	pH	TBAR		
Day		NS[k]	**[k]	**	**		
Fat[j]		**	**	*[k]	**		
Trt[j]		**	**	**	**		
Day x	Trt[j]	NS	NS	NS	NS		
Fat x	Trt[j]	**	NS	*	NS		
10	0	26.1[defg]	240.6	5.68[bcd]	.5637		
20	0	27.5[de]	114.4	5.73[abc]	.6157		
30	0	36.8[a]	128.8	5.79[a]	.3268		
10	5	25.7[defg]	247.3	5.66[cde]	.7011		
20	5	29.2[cd]	108.1	5.76[ab]	.8072		
30	5	32.8[bc]	110.9	5.78[a]	.4405		
10	10	27.8[de]	245.3	5.61[def]	.6644		
20	10	23.4[fgh]	120.3	5.59[ef]	.5719		
30	10	33.5[ab]	105.6	5.62[de]	.4324		
10	15	25.2[efgh]	242.8	5.58[ef]	.6299		
20	15	22.8[gh]	134.3	5.63[de]	.6111		
30	15	27.3[def]	116.7	5.53[f]	.4860	10	20
20	20	21.6[h]	138.3	5.61[def]	.6250		
30	20	26.2[defg]	138.9	5.65[cde]	.4220		
	SEM[l]	1.4410	7.090	.0286	.0449		
Fat x	Day	*	***		**		
10	0	27.5[c]	245.8[a]	5.76[ab]	.7186[b]	10	4
4		26.3[cd]	124.5[c]	5.65[cd]	.8432[a]		
20	24	24.9[d]	136.6[c]	5.61[de]	.6404[b]		
30	0	32.6[a]	88.4[e]	5.80[a]	.3765[d]	30	4

[abcdefgh] Means within columns with different superscripts are significantly different.

[i] Cook Loss expressed as %.

[j] TRT = time in seconds of surface flame application. FAT = expressed as %.

[k] NS = not significant; * = P<0.05; ** = P<0.01.

[l] SEM = standard error of the means.

TABLE 4. Bacterial populations of three fat levels of ground beef patties over storage time as affected by surface flaming.

FACTOR		APC	Anaerobes	Lactobacillus	Psychrotrophs
Day		**[j]	**	**	**
Fat[i]		**	**	**	**
Trt[i]		**	**	**	**
Day x	Trt[i]	NS	NS	**	*[j]
Fat x	Trt[i]	*	**	**	NS[j]
10	0	3.7[bc]	3.7[bc]	3.6[b]	3.4
20	0	4.8[a]	4.8[a]	4.8[a]	4.7
30	0	3.6[bc]	3.8[b]	3.5[bc]	3.2
10	5	3.3[cd]	3.1[de]	3.2[bcd]	3.3
20	5	4.0[b]	3.7[b]	3.4[bc]	4.1
30	5	3.2[cd]	3.2[de]	3.1[cde]	2.4
10	10	3.2[cd]	3.2[de]	2.8[def]	2.6
20	10	3.3[cd]	2.9[de]	2.7[ef]	3.7
30	10	2.9[de]	2.9[de]	2.6[fg]	2.3
10	15	2.7[ef]	3.0[de]	2.8[def]	2.7
20	15	3.5[c]	2.9[de]	3.0[def]	3.3
30	15	2.4[f]	2.7[e]	2.7[ef]	1.6
10	20	2.7[ef]	2.8[de]	2.2[g]	2.0
20	20	3.3[cd]	3.1[de]	3.0[def]	3.8
30	20	3.0[de]	2.7[e]	2.8[def]	1.6
	SEM[k]	.1574	.1701	.1521	.1859
Fat x	Day	NS	*	NS	*
10	0	3.0	2.8[d]	2.6	2.5[de]
10	4am[h]	2.8	3.0[cd]	2.8	2.5[de]
10	4pm[h]	3.5	3.5[b]	3.3	3.5[c]
10	24	3.3	3.2[c]	3.0	2.9[cd]
20	0	3.4	3.3[bc]	3.0	3.8[b]
20	4am	3.4	3.3[bc]	3.0	3.8[b]
20	4pm	4.4	4.3[a]	4.1	4.4[a]
20	24	4.0	3.0[cd]	3.3	3.3[c]
30	0	3.0	3.0[cd]	3.0	1.9[f]
30	4am	2.9	3.0[cd]	2.8	2.4[e]
30	4pm	3.3	3.3[bc]	3.2	2.6[d]
30	24	2.9	2.8[d]	2.8	1.9[f]
	SEM[k]	.1408	.1521	.1361	.1663

[abcdefg] Means within columns with different superscripts were significantly different.

[h] 4 am = frozen product; 4 pm = product thawed at room temperature for 6 hr.

[i] TRT = time in seconds of surface flame application. FAT = expressed as %.

[j] NS = not significant; * = P<0.05; ** = P<0.01.

[k] SEM = standard error of the means.