To the Graduate Council:

I am submitting herewith a thesis written by Thirakit Sathirakul entitled "Effect of Aging and Frozen Storage on Palatability and Chemical Characteristics of Grass-Fed Beef." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology and Science.

M. James Riemann

M. J. Riemann, Major Professor

We have read this thesis
and recommend its acceptance:

Curtis C. Melton

B. J. Demott

W. W. Overcast

Accepted for the Council:

Hilton A. Smith

Vice Chancellor
Graduate Studies and Research

EFFECT OF AGING AND FROZEN STORAGE ON PALATABILITY AND CHEMICAL CHARACTERISTICS OF GRASS-FED BEEF

A Thesis

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ABSTRACT

The effect of aging and frozen storage on chemical composition of uncooked grass-fed beef, palatability, cooking losses and Warner-Bratzler shear value of cooked product, effect of aging time on carcass surface microbial population, and cooler shrinkage were studied. Twenty-four left sides weighing 155 to 180 kg (175 to 200 lbs.) from grass-fed steer carcasses were aged either 0, 4, 8, or 12 days. Longissimus muscle samples of each side were assigned to 0, 30, and 60-day frozen storage periods. Neither aging or frozen storage affected protein, water or fat percentages of uncooked muscle. Sixty days frozen storage increased drip loss ($P<.001$) and total cooking loss ($P<.01$), but aging had no effect. Sensory panel evaluation showed eight days aging improved flavor ($P<.05$), juiciness ($P<.01$), tenderness ($P<.001$), and overall acceptability ($P<.001$). Thirty days frozen storage decreased juiciness ($P<.05$), tenderness ($P<.01$) and overall acceptability ($P<.01$), and 60 days frozen storage caused less desirable flavor ($P<.05$). Warner-Bratzler shear values increased ($P<.01$) with 60 days frozen storage but decreased ($P<.001$) with 8 days aging. Cooler shrinkage increased ($P<.01$) steadily up to 2.7 percent for sides aged 12 days. Microbial counts increased steadily during aging and highest counts were found on the flank followed by the neck, brisket, and outside round.

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CHAPTER I

INTRODUCTION

In the 1930's and 1940's, grass-belt beef producers marketed millions of grass-finished cattle. Beef from these rangy, usually well-matured cattle provided a welcome relief to menus crowded with pork and chicken. Rapidly increasing consumer incomes during and after World War II generated a demand for beef beyond the productive capability of the existing grazing acreage. This demand encouraged the development of a large commercial cattle feeding industry in the western plains. The creation of this new feeding industry made heavy grain-fed beef available to every supermarket. In 1972, grain-fed cattle marketing was estimated to have provided 75 percent of all commercial cattle slaughter. This proportion has risen dramatically since the early 1950's. It is unlikely, however, that this proportion will rise much further (Schupp and Monroe, 1973).

The setback in 1972 in world grain production and the purchases of large quantities of grains and other commodities by the USSR and Mainland China, as well as the more critical balance of supply and consumption in Asia and developing regions elsewhere, caused exceptionally large increases in the price of grain in the United States (Paxton 1974; Mackie 1974; and Vermeer et al. 1975). Since this situation, the meat industry tends to have shifted to use forage as feed for beef again. Beef finished on forage along, though less costly to produce, has lost favor in recent years. Forage finished beef is not a perfect substitute for grain finished beef. However, it can be used for specific retail beef uses and as a suitable substitute for the beef processing and food service markets (Schupp and Monroe 1973).

Cattle fed and finished on grass usually bring a lower price on the United States markets than similar cattle finished on grain. The reasons advanced for the price discrimination are many. One of the principle objections is that beef from cattle fattened on grass does not keep or age satisfactorily. The effect of pasture on the grade and palatability of beef therefore becomes a question of increasing importance. At the present time, grass-fed cattle consistently undersell grain-fed cattle.

In this study, an attempt was made to investigate the effect of aging and frozen storage on flavor, juiciness, tenderness, and overall acceptability of the cooked product; certain chemical characteristics of uncooked meat; drip and evaporative losses during cooking; and to determine the effect of aging time on microbial population on the carcass surface of grass-fed beef.

CHAPTER II

REVIEW OF LITERATURE

Effect of Pasture on Grade and Yield of Beef

Pasture is used in market beef production (a) as the only feed; (b) as the only feed for a limited time, followed by full feeding on pasture or in drylot or (c) supplemented by grain, followed sometimes by drylot feeding.

Cattle fattened on pasture alone with no grain or supplement, had lower slaughter grades than grain fed cattle (Black et al. 1940; Bull et al. 1941; Wanderstock and Miller 1948; Purchas and Davies 1974; and Marsh and Murdoch 1975). Average carcass grades were practically the same for grass-fed and grain-fed cattle (Hunt et al. 1953), but the carcasses of the cereal group had a slightly higher grade than the carcasses of the pasture group (Purchas and Davies 1974, and Siebert and Field 1975). Dressing percentage of grass-fed beef was lower than that of cattle fed grain because of less finish (Bull et al. 1941, and Hunt et al. 1953). Because of lower fat content (2.5 to 3.5 percent), and higher water content (72.5 to 75.5 percent), carcasses of pasture cattle shrink more in the cooler than carcasses of cattle full-fed in a drylot (Bray 1938; Bull et al. 1941; and Hunt et al. 1953). There is more yellow color in fat of carcasses of pasture cattle because of the transfer of carotene from pasture to body fat (Black et al. 1940; Bull et al. 1941; Wanderstock and Miller 1948; and Hunt et al. 1953). Cattle fattened on pasture do not produce dark lean (Black et al. 1940, and Bull et al. 1941).

Composition of Grass-fed Beef

Barbella et al. (1942) reported beef from grain-fed and grass-fed steers differed little in moisture, ash, protein, and ether extract (grain-fed: moisture = 73.6 percent, ash = 1.1 percent, protein = 22.5 percent, ether extract = 3.5 percent; grass-fed: moisture = 73.0 percent, ash = 1.1 percent; protein = 22.6 percent, and ether extract = 3.9 percent). Compositional changes that occurred during 15.7 days of aging were similar for both types of beef (Barbella et al., 1942). Wanderstock and Miller (1948) reported the physical analysis of the left 9-10-11th rib-section indicated that the pasture-only carcasses which graded average commercial, had smaller proportions of meat to bone than grain-fed carcasses. Purchas and Davies (1974) found Friesian steers fed barley grew 31 percent faster than Friesian steers fed on pasture. The carcasses of the barley-fed were fatter, especially with regard to omental fat ($P<.001$), intramuscular fat ($P<.005$) and dissectable fat from the 9-10-11 rib cut ($P<.005$).

Lean and Fat Color of Grass-fed Beef

Color of lean and in some cases color of fat are two criteria by which consumers measure quality and desirability of beef (Craig et al. 1959). Pasture is accused of producing dark lean and yellow fat. This is a serious charge since the color of both lean and fat of beef is important in determining carcass grade and consequently the price paid for the live cattle. The lean of beef should be a bright cherry-red color. Consumers prefer white or creamy white beef fat. Yellow fat is an indication of inferior breeding and of advanced age, and consumers associate yellow fat with tough, stringy, unpalatable meat (Black _et al_. 1940; Bull _et al_. 1941; Wanderstock and Miller 1948; and Craig _et al_. 1959).

Many researchers reported there was no difference between color of lean of cattle fed pasture and cattle fed grain (Longwell 1936; Black _et al_. 1940; Bull _et al_. 1941; and Craig _et al_. 1959). Bull _et al_. (1941) reported the kind of pasture used had no relation to the color of beef fat and the amount of yellow in the fat of pasture-fed cattle depended on the transfer of carotene from pasture to body fat. Black _et al_. (1940) concluded yellow fat was more desirable than white fat nutritionally because yellow fat contained more vitamin A due to higher carotene content.

Carcass Shrinkage

The carcasses of pasture-fed cattle shrank more in the cooler than the carcasses of cattle full-fed in drylot because of a lower fat and higher water content (Bull _et al_. 1941). Hunt _et al_. (1953) reported an average difference of 1.7 pereent greater shrink for carcasses of grass-fed cattle than for grain-fed cattle.

Effect of Aging on Palatability Characteristics

Black _et al_. (1940); Callow (1961); McCullough (1970); Oltjen _et al_. (1971); Purchas and Davies (1974), and Marsh and Murdoch (1975) found little or no differences in tenderness or other palatability factors between beef from animals fed grass exclusively and those fed grass supplemented with concentrates. In contrast, Black et al. (1931); Bull et al. (1941); Wanderstock and Miller (1948); Meyer et al. (1960), and Bond et al. (1972) found beef from animals fattened on pasture alone to have poorer eating qualities than that from animals fed supplements, or fed in drylot. However, all the beef was scored acceptable. Purchas and Davies (1974) reported cattle fed on pasture produced leaner carcasses and tougher meat, with less acceptable flavor than cattle fed on cereal grain.

Tenderness. The tenderness and flavor of the meat from cattle finished on cereals were superior in some studies (Black et al. 1931; Wanderstock and Miller 1948; Meyer et al. 1960, and Bond et al. 1972), although other researchers have found little or no difference (Black et al. 1940; Callow 1961; McCullough 1970, and Oltjen et al. 1971).

Meyer et al. (1960) reported aging caused an improvement ($P<.001$) in the tenderness of both grain- and grass-finished beef whether measured by panel or shear value. Most of the increase in tenderness occurred during the first 21 days of aging. Beyond this point, panel scores and shear values for the loin roasts tended to level off. The round roasts continued to increase in tenderness but at a slower rate, up to 42 days of aging. Purchas and Davies (1974) agreed that tenderness of meat from grass-fed animals tended to improve with aging.

Flavor. Barbella et al. (1942) found little or no difference in flavor and aroma of meat from grain-fattened and grass-fattened steers after 15.7 and 50 days of aging. Meyer et al. (1960) reported the flavor of lean of the grain-finished beef tended to improve up to 21 days of aging, but the flavor of lean of the grass-finished beef showed little or not improvement during aging. After 21 days, the scores for flavor of lean decreased (P<.001) for both groups of beef. The greatest sensory difference between the two types of beef was observed in the flavor of the fat. Flavor of fat of both types of beef was impaired (P<.001) after 21 days of aging.

Juiciness. Barbella et al. (1941) found no difference expressible juice from beef of grass-fattened and grain-fattened cattle that had been aged 15.7 to 50 days. In contrast, Meyer et al. (1960) found grain-finished beef was scored more juicy (P<.001) than the grass-finished beef. Purchas and Davies (1974) reported juiciness of meat in the cattle fed on cereal was more acceptable than in the pasture group, but the difference was not significant.

Juiciness was not affected by aging according to Meyer et al. (1960).

Cooking Losses. Wanderstock and Miller (1948) reported cooking losses of meat from beef fattened on grass was not different from beef fattened on grain. Bull et al. (1941) reported the ribs from the steers fed on grass only lost more weight by evaporation than those fed on grain, however, there were no differences in total cooking losses. Meyer et al. (1960) reported overall differences in drip loss, evaporation loss, and total cooking losses due to feed were not significant.

Aging produced a progressive increase (P<.001) in drip loss and in total losses. Evaporation loss was not affected by aging (Meyer et al. 1960).

Quality as Affected by Frozen Storage

Investigators have reported no effect, increased tenderness, and decreased tenderness as the result of frozen storage of beef (Khan et al. 1963; Partmann 1963; and Price and Schweigart 1971). The process of freezing, itself, has no demonstrable effect upon the color, flavor, odor or juiciness of meat after cooking, however, freezer storage resulted in a gradual decrease in odor and flavor (Price and Schweigart 1971).

Microbiological Criteria for Fresh Meat

It was stated in the 1930's, and often later, that when chilled meat in carcass or larger cuts has a surface load of bacteria approximating 5×10^7 to 10^8 organisms per square cm., the meat develops off-flavor and discoloration and the surface gets sticky or slimy (Ayres 1955; Angelotti et al. 1958, and Ayres 1960). The meat passes what is often named "the slime limit." The time required for bacteria to reach this level is very closely related to the number of organisms present when the storage period begins. This means a decrease in initial number of psychrophilic microorganisms automatically gives an increase in shelf-life (Angelotti et al. 1958; Ayres 1960, and Jaye et al. 1962). There is no direct correlation between maximum bacterial count and acceptability limit. When maximum has been reached, there is still a considerable period of storage time left, until a consumer panel begins to complain about a "sour" or "old" taste (Baltzer 1969, and Kotula 1970). Baltzer (1969) indicated that 60 samples taken at 6 locations on 10 carcasses was the maximum number necessary to get reproducible results with at least some correlation to what is found in the meat industry.

CHAPTER III

MATERIALS AND METHODS

The left side of 24 steer carcasses weighing 155 to 180 kg (350 to 400 lbs) with A maturity and no more than 0.2 inch (0.5 cm) of external fat were selected at two local packing plants 24 hours postmortem. The 24 sides were transported to the University of Tennessee Meat Laboratory and assigned to an aging treatment of 0, 4, 8, or 12 days. The sides were aged at 34°F (1.1°C).

Surface microbial counts were determined on each side within each aging treatment by swabbing a 10 cm^2 area over the neck, brisket, flank, and outside round (Hansen 1962). Carcass shrinkage was determined for each carcass within each aging treatment. Side weights were taken before and after aging to determine cooler shrinkage.

At completion of each aging treatment, one inch (2.54 cm) thick *longissimus* muscle samples were cut, wrapped in heavy freezer wrapping paper, and assigned to a frozen storage treatment. The samples were quick frozen 12 hours at -30°F (-34.4°C) then stored at 0°F (-17.8°C) until analyzed according to the following allotments:

Analysis	Frozen Treatment	Sample Location
Chemical analysis	0 days	8th and 9th Rib steaks
Chemical analysis	30 days	10th and 11th Rib steaks
Chemical analysis	60 days	12th and 13th Rib steaks
Taste panel	0 days	2nd Loin steak
Taste panel	30 days	3rd Loin steak

Analysis	Frozen Treatment	Sample Location
Taste panel	60 days	4th Loin steak
Mechanical shear	0 days	5th Loin steak
Mechanical shear	30 days	6th Loin steak
Mechanical shear	60 days	7th Loin steak

Zero aging time was at 24 hours postmortem.

Upon completion of the respective frozen storage periods, the frozen steak samples were thawed 5-6 hours at room temperature. The *longissimus* muscle was removed from the steak, ground 3 times through a 1/8 inch plate, than packed into a whirl-pak bag and stored at 32°F (0°C) until analyzed.

Total nitrogen was determined by the Kjeldahl method (A. O. A. C. 1970) using a 1.0 g sample. Total apparent protein was calculated by using a conversion factor of 6.25.

The petroleum ether extract method (Goldfish) was used for the determination of neutral lipids (A. O. A. C., 1970). About 1.5 g of moisture-free sample was extracted 8 hours with petroleum ether.

Moisture content of the ground sample was determined by drying a 7 g sample 18 hours in a vacuum oven at 90°C (A. O. A. C. 1970).

Frozen steak samples for taste panel and Warner-Bratzler shear tests were thawed 24 hours in a refrigerator at 40°F (4.4°C) before cooking. The steaks were broiled to an internal temperature of 150°F (65.5°C) in a rotary hearth oven preheated to 350°F.

A seven member sensory evaluation panel scored one-half inch cores for tenderness, flavor, juiciness, and overall acceptability. Scoring was done on a 9-point hedonic scale in which 9 = extremely desirable, 5 = acceptable, and 1 = extremely undesirable.

Ten, half-inch cores were taken from the longissimus muscle of each steak after cooking and cooled to room temperature for shearing. Each core was sheared once.

The difference in weight of pan, rack, and steak before and after cooking was used to determine evaporation loss. The difference in weight of pan, rack and drip from the steak before and after cooking was used to determine drip loss. The combination of evaporation loss and drip loss gave the total cooking loss of each steak.

The data were analyzed by analysis of variance (Steele and Torrie 1960), and differences between individual means were determined by Duncan's Multiple Range Test (Steele and Torrie 1960). Statistical analysis of carcass weight losses during aging was done by one-way analysis of variance.

CHAPTER IV

RESULTS AND DISCUSSION

The variance ratios (F-value) for the chemical-composition, cooking losses, palatability scores, and Warner-Bratzler shear values are shown in Table 1.

Means and standard deviations of longissimus muscle chemical composition for the respective aging and frozen storage treatments are shown in Table 2. Protein, fat and moisture percentages were not affected by aging or frozen storage. However, the aging x frozen storage interaction decreased ($P<.05$) water content and increased ($P<.05$) fat content. Barbella et al. (1942) reported aging had no effect on the chemical composition of grass-fed beef.

Aging up to 8 and 12 days improved ($P<.05$) flavor desirability (Table 3). Aging afforded little or no improvement in flavor of grass-fed beef according to Meyer et al. (1960). Thirty days of frozen storage tended to decrease flavor scores, and flavor desirability was reduced ($P<.05$) after 60 days of frozen storage. Price and Schweigart (1970) also found that freezer storage resulted in a gradual decrease in odor and flavor acceptability.

Aging 8 and 12 days improved ($P<.01$) juiciness of the beef (Table 3). Frozen storage for 30 and 60 days decreased ($P<.05$) juiciness as judged by the taste panel. Price and Schweigart (1970) indicated moisture loss of meat during storage can cause changes which affect eating quality. Usually, good quality can be maintained for

TABLE 1

VARIANCE RATIOS (F-VALUE) FOR CHEMICAL COMPOSITION, COOKING LOSSES, PALATABILITY SCORES, AND WARNER-BRATZLER SHEAR VALUES

	Aging	Frozen Storage	Aging x Frozen Storage
Chemical composition			
Protein	0.34	0.01	1.47
Water	1.78	0.33	3.16*
Fat	0.60	0.95	2.81*
Cooking losses			
Drip loss	0.94	12.88***	0.62
Evaporation loss	2.34	2.16	0.79
Total loss	0.13	6.66**	0.36
Palatability scores			
Flavor	4.93*	3.79*	4.10**
Tenderness	12.31***	7.16**	0.31
Juiciness	6.65**	5.09*	0.64
Overall acceptability	12.97***	7.63**	0.77
Warner-Bratzler shear	11.70***	7.85**	1.29

*P <.05.

**P <.01.

***P <.001.

TABLE 2

MEAN AND STANDARD DEVIATION OF CHEMICAL COMPOSITION OF LONGISSIMUS MUSCLE AFTER AGING AND FROZEN STORAGE TREATMENTS

	Protein (%)[4]	Water (%)[5]	Fat (%)[6]
Frozen storage (days)[1]			
0	21.22 ± 1.05^a	74.42 ± 1.09^a	2.34 ± 0.67^a
30	21.20 ± 1.04^a	74.34 ± 1.07^a	2.38 ± 0.68^a
60	21.22 ± 0.83^a	74.34 ± 1.05^a	2.33 ± 0.69^a
	Protein (%)[7]	Water (%)[8]	Fat (%)[9]
Aging period (days)[2]			
0	20.92 ± 0.92^x	74.32 ± 0.56^x	2.11 ± 0.58^x
4	21.19 ± 0.74^x	74.13 ± 1.24^x	2.53 ± 0.90^x
8	21.48 ± 1.24^x	75.15 ± 1.05^x	2.21 ± 0.35^x
12	21.26 ± 1.34^x	73.98 ± 0.92^x	2.55 ± 0.75^x
Overall mean[3]	21.21 ± 0.97	74.39 ± 1.06	2.35 ± 0.69

[1] Means include 24 observations.

[2] Means include 18 observations.

[3] Means include 72 observations.

[4,5,6,7,8,9] Means within each column having the same superscript are not significantly different ($P<.05$).

TABLE 3

MEAN AND STANDARD DEVIATION OF PALATABILITY SCORES[1] AND WARNER-BRATZLER SHEAR OF <u>LONGISSIMUS</u> MUSCLE AFTER AGING AND FROZEN STORAGE TREATMENT

Frozen storage[2] (days)	Flavor*	Juiciness*	Tenderness**	Acceptability**	Shear[5] (lbs)**
0	5.57 ± 0.67^{a}	6.12 ± 0.77^{a}	6.04 ± 1.20^{a}	5.69 ± 0.84^{a}	7.32 ± 2.51^{a}
30	5.35 ± 0.57^{ab}	5.52 ± 0.76^{b}	5.32 ± 1.27^{b}	5.19 ± 0.79^{b}	7.96 ± 3.12^{ab}
60	5.22 ± 0.78^{b}	5.56 ± 0.84^{b}	5.62 ± 1.32^{ab}	5.21 ± 0.97^{b}	8.55 ± 2.96^{b}
Aging period[3] (days)	Flavor*	Juiciness**	Tenderness***	Acceptability***	Shear (lbs)***
0	4.87 ± 0.74^{x}	5.17 ± 0.82^{x}	4.22 ± 0.84^{x}	4.41 ± 0.64^{x}	11.48 ± 2.34^{x}
4	5.34 ± 0.45^{xy}	5.66 ± 0.62^{xy}	5.55 ± 0.64^{xy}	5.27 ± 0.39^{xy}	7.66 ± 2.04^{xy}
8	5.70 ± 0.61^{y}	6.22 ± 0.62^{y}	6.53 ± 1.17^{y}	6.01 ± 0.79^{y}	6.77 ± 2.03^{y}

TABLE 3 (continued)

Aging period[3] (days)	Flavor*	Juiciness**	Tenderness***	Acceptability***	Shear (lbs)***
12	5.60 ± 0.53^{Y}	5.89 ± 0.94^{Y}	6.34 ± 0.80^{Y}	5.77 ± 0.72^{Y}	5.88 ± 1.25^{Y}
Overall means[4]	5.38 ± 0.66	5.74 ± 0.84	5.66 ± 1.28	5.36 ± 0.89	7.95 ± 2.88

[1]A trained panel of 7 judges scored the meat using a 9-point hedonic scale ranged from 9 = extremely desirable, 5 = acceptable and 1 = extremely undesirable.

[2]Mean includes 24 observations.

[3]Mean includes 18 observations.

[4]Mean includes 72 observations.

[5]Force (lbs) required to shear a 1/2 inch core.

*Means within the column having the same superscript are not significantly different ($P<.05$).

**Means within the column having the same superscript are not significantly different ($P<.01$).

***Means within the column having the same superscript are not significantly different ($P<.001$).

several months by observing suitable precautions. Tight-fitting, moisture-proof packaging and steady storage temperature, -18°C (0°F) or lower, are the most critical requirements (Price and Schweigart, 1970). The aging x frozen storage interaction had no effect on juiciness.

Tenderness was increased ($P<.001$) by aging 8 and 12 days as determined by sensory panel and shear values (Table 3). Panel tenderness scores showed the greatest increase in tenderness occurred from 0 to 4 days but tenderness changes were not statistically significant until 8 days of aging ($P<.001$). Shear values showed a steady increase ($P<.001$) in tenderness from aging up to 12 days with the greatest increase occurring the first 4 days. Meyer et al. (1960) reported that the increase in tenderness of grass-fed beef occurred after 21 days of aging. Beyond this point, panel scores and shear values tended to level off (Meyer et al., 1960). Frozen storage tended to decrease the tenderness of beef according to panel and shear values (Table 3). Sensory scores of the panel showed 30 days of frozen storage decreased ($P<.01$) steak tenderness. Panel tenderness scores for steaks stored 60 days were not statistically different from the 0 or 30 days frozen storage groups. Warner-Bratzler shear values showed a steady decrease ($P<.01$) in tenderness from 0 to 60 days of frozen storage. Price and Schweigart (1970) suggested that the tenderizing effect of freezing and frozen storage is positive and more pronounced if the time between slaughter and freezing is short and that younger animals and certain muscles (e.g. round rather than neck or shank muscles) are affected the most. The interaction between aging x frozen storage had no effect on tenderness whether measured by taste panel or by mechanical shear.

Overall acceptability scores (Table 3) were higher ($P<.01$) for steaks from sides aged 8 and 12 days compared to 0 days aging. Panel members scored samples aged 8 days highest. Frozen storage for 30 and 60 days decreased ($P<.01$) acceptability according to the sensory panel. The aging x frozen storage interaction had no effect on overall acceptability.

Mean and standard deviation of cooking losses after aging and frozen storage treatments are shown in Table 4. Overall differences in drip losses, evaporation losses, and total cooking losses due to aging were not significant. However, 60 days of frozen storage increased drip loss ($P<.001$) and total loss ($P<.01$) during cooking. Frozen storage for 30 days increased nonsignificantly both drip loss and total cooking loss. Frozen storage had no effect on evaporation loss. Meyer et al. (1960) reported that aging produced increased ($P<.01$) drip losses and total losses, but evaporation losses were unaffected. The aging x frozen storage interaction had no effect on drip loss, evaporation loss and total cooking loss in this study.

Mean weight losses of beef sides during the different aging periods are shown in Table 5. As the time of aging increased, weight losses of the carcasses increased ($P<.01$) steadily.

Surface microbial counts are shown in Table 6 and Figure 1. As the time of aging increased, microbial counts on neck, brisket, flank and outside round areas increased steadily which agreed with the report of Baltzer (1969). Microbial counts from highest to lowest were on the flank, neck, brisket and outside round areas respectively

TABLE 4

MEAN AND STANDARD DEVIATION OF COOKING LOSSES OF *LONGISSIMUS* MUSCLE AFTER AGING AND FROZEN STORAGE TREATMENTS

	Drip loss (%)***	Evaporation loss (%)*	Total loss (%)**
Frozen storage (days)[1]			
0	5.13 ± 1.60^{a}	8.04 ± 1.56^{a}	13.18 ± 2.81^{a}
30	6.08 ± 1.84^{ab}	8.14 ± 1.24^{a}	14.21 ± 2.46^{ab}
60	6.49 ± 1.93^{b}	8.66 ± 1.36^{a}	15.15 ± 2.98^{b}
	Drip loss (%)*	Evaporation loss (%)*	Total loss (%)*
Aging period (days)[2]			
0	6.47 ± 1.43^{x}	7.97 ± 0.95^{x}	14.45 ± 1.98^{x}
4	6.34 ± 1.27^{x}	7.56 ± 0.85^{x}	13.90 ± 1.96^{x}
8	5.73 ± 2.41^{x}	8.80 ± 1.47^{x}	14.54 ± 3.65^{x}

TABLE 4 (continued)

	Drip loss (%)*	Evaporation loss (%)*	Total loss (%)*
Aging period (days)[2]			
12	5.06 ± 1.92^{x}	8.78 ± 1.78^{x}	13.84 ± 3.48^{x}
Overall means[3]	5.90 ± 1.86	8.28 ± 1.40	14.18 ± 2.84

[1]Means include 24 observations.

[2]Means include 18 observations.

[3]Means include 72 observations.

*Means within the same column having the same superscript are not significantly different ($P<.05$).

**Means within the same column having the same superscript are not significantly different ($P<.01$).

***Means within the same column having the same superscript are not significantly different ($P<.001$).

TABLE 5

MEAN WEIGHT LOSSES OF BEEF SIDES
AFTER AGING AT 34 $\pm$ 2°F

Aging period (days)[1]	Weight losses (%)**
0	0.0[a]
4	1.14[b]
8	1.69[c]
12	2.70[d]

[1]Means include 6 observations.

**Means within the column having a different superscript are sifnificantly different (P<.01).

TABLE 6

MEAN AND RANGE OF MICROBIAL COUNT/CM^2 ON NECK, BRISKET, FLANK, AND ROUND AREAS OF BEEF CARCASSES AT DIFFERENT AGING TIMES

Group I.[1] Sides aged 0 days		
	0 Day	
Neck	96 (25 - 284)	
Brisket	51 (3 - 207)	
Flank	93 (8 - 182)	
Round	54 (3 - 186)	
Group II.[1] Sides aged 4 days		
	0 Day	4 Days
Neck	23 (5 - 40)	394 (16 - 2,000)
Brisket	2 (0 - 4)	6 (0 - 14)
Flank	1 (0 - 6)	6 (0 - 20)
Round	10,217 (20 - 30,000)	79,578 (50 - 254,000)

TABLE 6 (continued)

Group III.[1] Sides aged 8 days				
	0 Day	4 Days	8 Days	
Neck	11 (0 - 31)	38 (4 - 120)	25,183 (6,800 - 31,700)	
Brisket	3 (0 -8)	16 (2 - 49)	14,412 (470 - 30,000)	
Flank	2 (0 - 4)	6 (2 - 12)	23,883 (600 - 30,000)	
Round	6,659 (3 - 28,700)	7,426 (15 - 32,000)	2,894 (143 - 4,900)	
Group IV.[1] Sides aged 12 days				
	0 Day	4 Days	8 Days	12 Days
Neck	18 (0 - 90)	97 (18 - 297)	3,868 (70 - 17,800)	85,585 (1,650 - 300,000)
Brisket	23 (0 - 120)	37 (0 - 170)	125 (0 - 510)	65,573 (840 - 300,000)
Flank	7 (0 - 40)	44 (0 - 172)	248 (0 - 950)	102,757 (200 - 300,000)
Round	125 (0 - 620)	101 (0 - 215)	305 (0 - 510)	1,337 (0 - 14,200)

[1]Means include 6 observations.

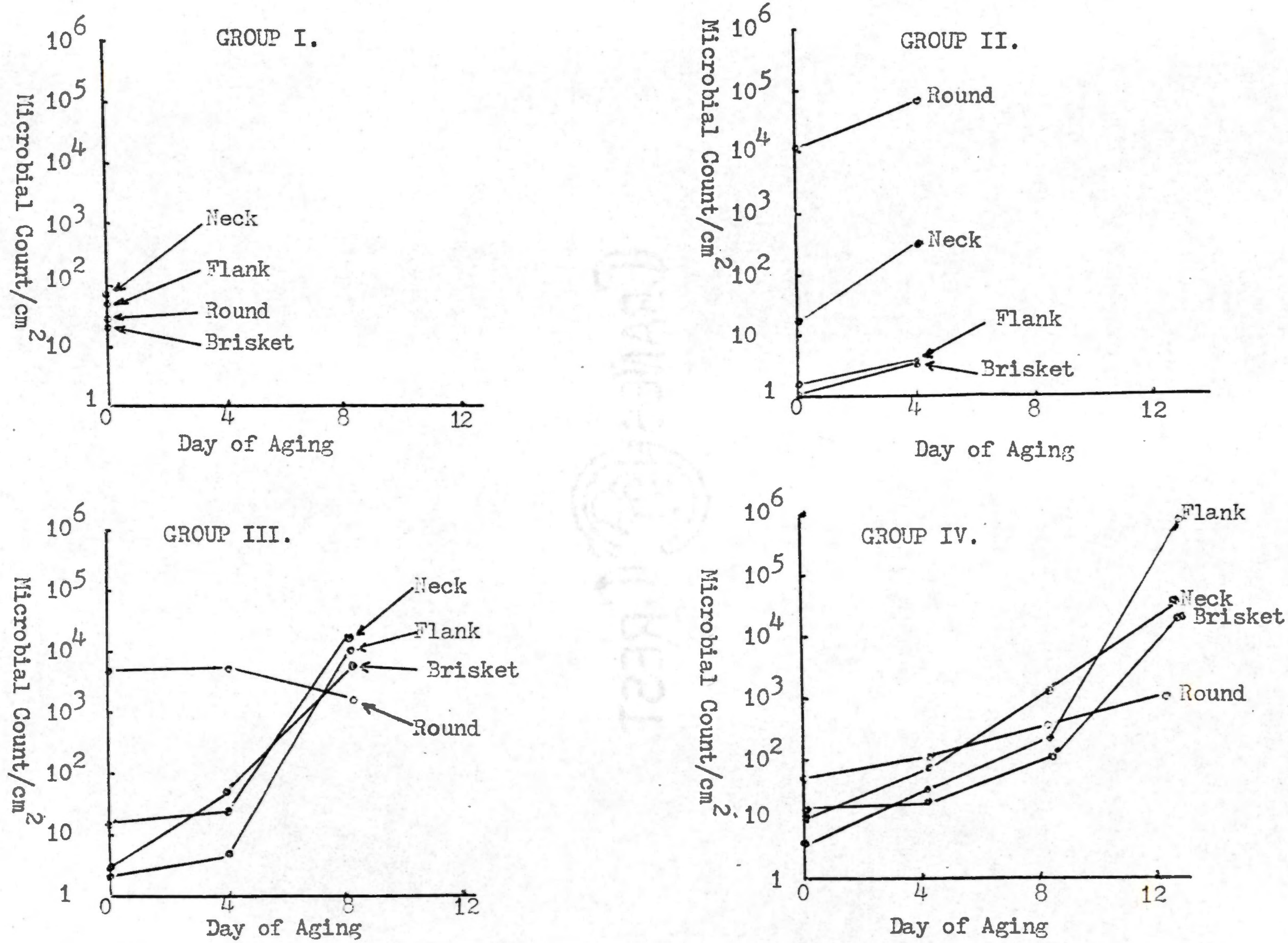

Figure 1. Mean microbial count/cm^2 on beef carcasses at different periods of aging time.

after 12 days of aging. This can be explained by the fact that the brisket and the outside round areas are coverd by a layer of fat and connective tissue which has poor nutrient qualities for most organisms, while flank and neck areas have a small amount of fat and connective tissue cover (Ayres 1955). In addition, the round was exposed to more air ciculation which caused drying of the surface.

CHAPTER V

SUMMARY

The effect of aging and frozen storage on chemical composition of uncooked grass-fed beef, palatability, cooking losses and Warner-Bratzler shear value of cooked product, and effect of aging on surface microbial population and carcass shrinkage were studied. Twenty-four sides from grass-fed beef carcasses were brought from two local packing plants, divided into four groups and aged 0, 4, 8 or 12 days at 34°F. Cooler shrinkage and microbial population on the side surface was determined. At completion of the aging period, 2.54 cm (1 inch) thick _longissimus_ muscle samples were removed and assigned to a frozen storage treatment (0, 30 or 60 days).

Chemical composition (percent protein, fat and water) of grass-fed beef was not affected by aging or frozen storage. Aging generally improved palatability characteristics of the beef. Sensory panel scores were highest for flavor ($P<.05$), juiciness ($P<.01$), tenderness ($P<.001$) and overall acceptability ($P<.001$) for samples aged 8 days. Warner-Bratzler shear results also showed increased ($P<.001$) tenderness with aging. Effects of frozen storage were opposite those of aging. Frozen storage for 30 days decreased juiciness ($P<.05$), tenderness ($P<.01$) and overall acceptability ($P<.01$). Sixty days of frozen storage resulted in less desirable ($P<.05$) flavor of the cooked product. Warner-Bratzler shear values steadily increased ($P<.01$) as frozen storage was extended from 0 to 60 days. Aging did not affect drip losses, evaporation losses, or total cooking losses. Similarly, frozen storage did not

affect evaporation losses. However, 60 days of frozen storage did increase drip loss ($P<.001$) and consequently increased total cooking loss ($P<.01$). Aging caused a steady increase ($P<.01$) in weight losses of the sides. Aging caused a steady increase in surface microbial count of the sides.

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VITA

The author was born on January 7, 1953, in Songkhla, Thailand. He completed his Higher School Certificate course at Bhumipol King's College in Sam-parn in 1970. He entered Kasetsart University and graduated with a Bachelor of Science degree in Food Science in 1974. In January, 1975, he enrolled in the Department of Food Technology of the University of Tennessee, Knoxville. Since that time, he has been working to complete the requirements for the degree of Master of Science.