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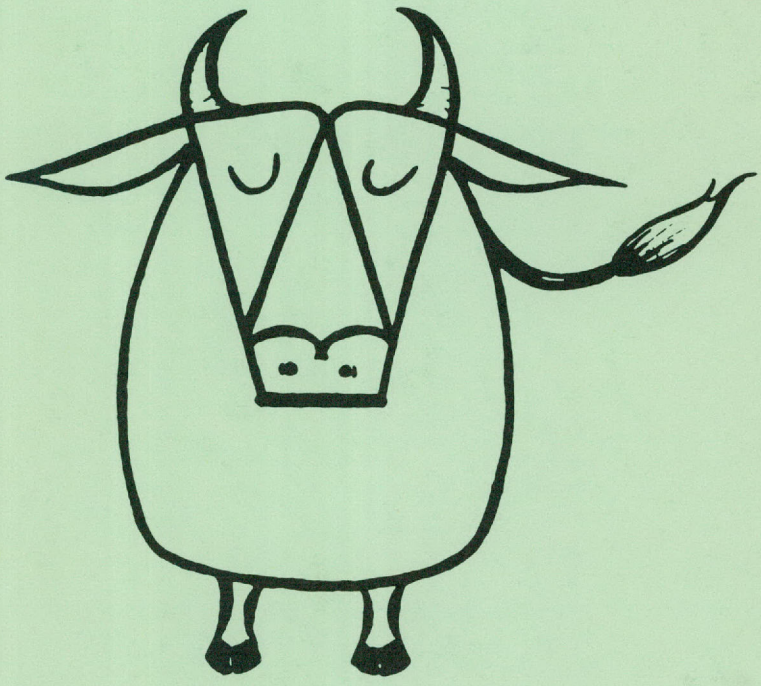
Beef Cattle Research in Texas, 1982



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Metric Units - English Equivalents

Metric Unit	*English Equivalent*
Centimeter	0.394 inch
Hectare	2.47 acres
Kilogram	2.205 pounds
Kilogram per hectare	0.893 pounds per acre
Kilometer	0.62 statute mile
Kilometer per hour	0.62 miles per hour
Liter	0.264 gallons
Meter	3.28 feet
Square meter	10.758 square feet
(Degrees centigrade $\times 1.8 + 32$)	Degrees fahrenheit

The production and distribution of wholesome, safe, and inexpensive food is a critical and pervasive concern in the 1980's. The impact will be evident to the citizens of Texas and the nation. Consumers expect readily available food at a price lower than in other developed countries. Critical impacts of inflation, energy, water resources and other natural resources require improved production methods and new goals. The Texas Agricultural Experiment Station is targeting research to respond to these needs through the development of improved and new technology.

Research is the dominant factor in improving agricultural productivity. Ultimately the consumer receives the major benefit from this research through improved quality and assured supply of food and fiber. Texas Agricultural products are vital to the economic well-being of every Texan through both domestic use and the advantages gained from exports and foreign markets.

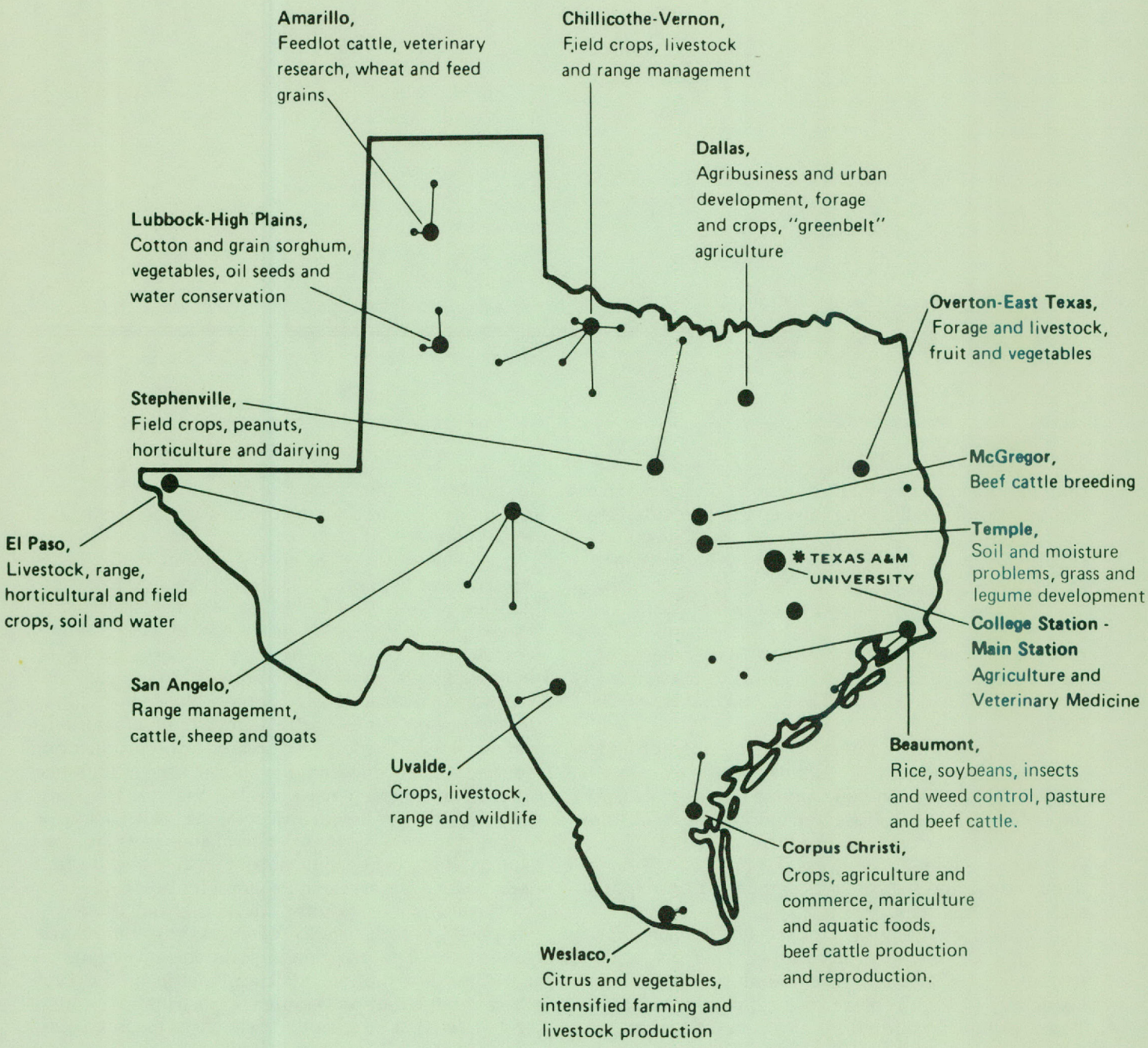
Texas beef herds on January 1, 1981 contained 13.7 million cattle and calves or 11.9 percent of the U.S. total. Beef cows in Texas numbered 5.9 million head, 15.1 percent of the U.S. beef cow population. Texas feedlots accounted for 17.9 percent of the U.S. fed cattle marketings during 1980. Texas produced 17.1 percent of the 33.8 million head of commercial cattle slaughtered in the U.S. during 1980. Beef cattle are the single most important contributors to agricultural cash receipts in Texas. During 1979, cash receipts from beef cattle totaled $4.9 billion for 49 percent of the $10 billion agricultural cash receipts in Texas. Beef production is a land-based industry. Cattle provide an effective means of harvesting range and pasture resources, while also utilizing harvested roughage, by-product feeds, industrial waste and feed grains.

The beef cattle research program of the Texas Agricultural Experiment Station is planned and organized within the TAES Five-year Research and Development Plan. The focus of the beef cattle research program is to develop understanding of biological and physical phenomena to provide the technology needed to alleviate constraints most likely to impinge on the competitive development and utilization of Texas resources for beef cattle production, processing and distribution. To best serve the public interest a comprehensive beef cattle research program is oriented toward developing technology for optimizing the conversion rate of these available resources into beef of high nutritive value and desired palatability. The research program for beef cattle may be viewed as a continuum extending from "basic" to "applied" with a balance of efforts throughout the continuum. The program is planned and organized with consideration to all components of the beef cattle production, processing and distribution system and directed at increasing efficiency of resource utilization.

The Beef Cattle Research in Texas — 1982 publication is intended to provide progress reports and briefs of research conducted in support of the beef cattle industry.

Neville P. Clarke
Director

THE TEXAS A&M UNIVERSITY SYSTEM
RESEARCH AND EXTENSION CENTERS



Beef Cattle Research in Texas, 1982

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PR-3916

Effect of 48-Hour Calf Removal Regimes, Prior to Controlled Breeding, on Reproductive Performance

D. W. Forrest, J. E. Huston, and J. R. Beverly

A prostaglandin, Lutalyse (Upjohn Company), is now available for synchronization of estrus in cattle. Synchronization facilitates the use of artifical insemination (AI) in beef cows. The combined synchronization/AI procedure can be described as a controlled breeding program. Numerous studies have proven it is possible, under optimum conditions, to achieve acceptable pregnancy rates with controlled breeding. However, cows or heifers must have initiated the estrous cycle as a prerequisite for exhibiting a fertile estrus in response to the synchronization treatment.

A high incidence of anestrus (non-cycling) cows or heifers at the start of the breeding season in Texas impedes the use of this type of breeding program. Weaning calves early or limiting the frequency of suckling can increase the proportion of lactating cows that are cycling before breeding begins.

The objectives of this study were to determine the effect of short-term calf removal (48 hours) on occurrence of estrus and subsequent pregnancy rates after a single fixed-time AI in synchronized cows. All cows received the conventional two-Lutalyse injection sequence at 11-day intervals for synchronization of estrus. Each cow was inseminated approximately 80 hours after the second Lutalyse injection. Trials were conducted at four locations. Cows were allotted by breed, age, calving date and body condition to a normally suckled control (C) or a 48-hour calf removal (CR) treatment group. CR was employed at one or more of the following times at each location: 10 days before the first Lutalyse injection (CRO), on the day of first Lutalyse injection (CR1) and on the day of the second Lutalyse injection (CR2). Estrus was monitored during the treatment period by the application of a Kamar heat mount detector (HMD) to the rump of each cow. Pregnancy data have been obtained on cows from one of the four locations.

A total of 96 Hereford and Brangus × Hereford cows were allotted to either C or CRO plus CR1 (CRO1) treatments. Cows with either activated or missing HMD's were assumed to have been in standing estrus. This method may overestimate the actual

percentage of cows in estrus due to potential loss of HMD's for reasons other than mounting activity. The percentage of cows classified in estrus at least once before breeding was 77.1 pecent and 81.2 percent for C and CRO1, respectively. Pregnancy rates were similar for cows in the C (39.6 percent) and CRO1 (33.3 percent) treatments. The percentage of cows that were in estrus twice during the treatment period but did not conceive to the controlled breeding (20.7 percent of nonpregnant C and 34.3 percent of nonpregnant CRO1) falls within the normal range for conception rate. In addition, some cows that conceived were not detected in estrus before controlled breeding (21.1 percent and 25.0 percent of the pregnant C and CRO1 cows, respectively).

These preliminary data suggest that under conditions at one location: 1) HMD's did aid in estimating the percentage of estrous cycling cows; 2) removal of calves for 48 hours at two separate periods did not enhance subsequent pregnancy rates.

PR-3917

Embryo Transfer Techniques for Diagnosis of Infertility in Cattle

D. C. KRAEMER AND D. R. BARRIOS

Summary

Although the study has not yet been completed, it is apparent that embryo collection techniques can be used to rule out fertilization failure as the reason for infertility in some repeat breeder cows. Early results from the embryo transfer trials would suggest that some infertile cows can be impregnated if a normal embryo is transferred to their uterus. It remains to be seen whether these pregnancies will continue to term.

These techniques are relatively expensive and the capabilities for performing them are not widespread. However, they may be appropriate for a more complete differential diagnosis of infertility of the genetically valuable female than would otherwise be possible.

Introduction

It is often difficult to determine whether the infertility of a repeat breeder cow is due to failure of egg fertilization or to early embryonic mortality. This study is being conducted to determine if procedures developed for embryo transfer would be useful for differentiating between these two causes of infertility. Nonsurgical embryo collection techniques are being evaluated for use as a diagnostic tool for determining if the egg is being fertilized following insemination. Embryos from proven fertile cows are being transferred to repeat breeder cows to determine if those cows are capable of maintaining pregnancy after the first week of development.

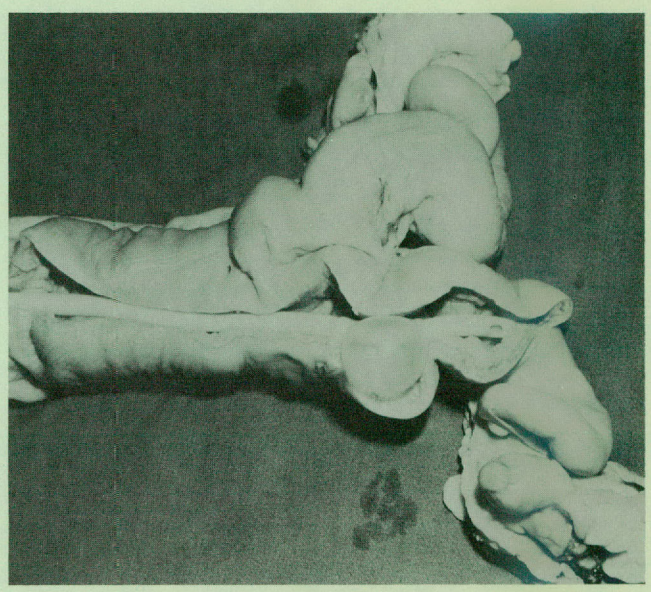

Figure 2. A photographic illustration of the Foley catheter, with the balloon inflated, in place within the uterine horn.

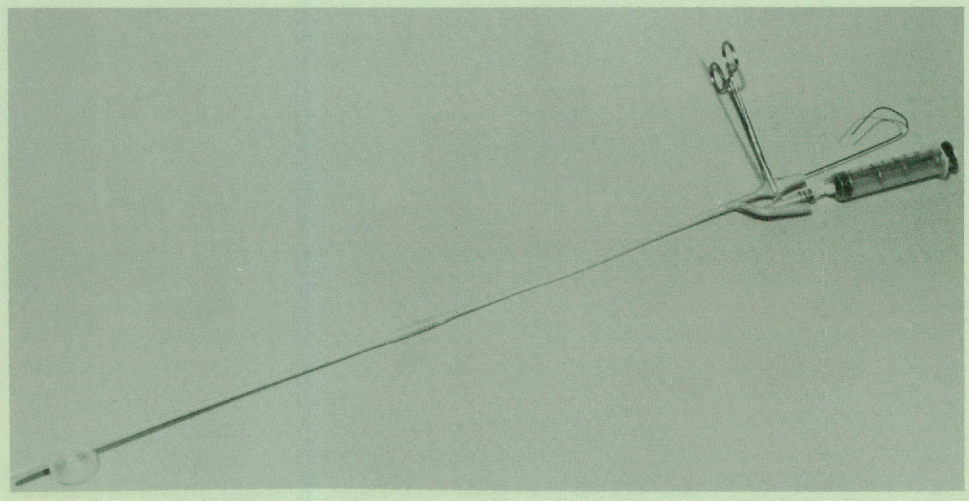

Figure 1. The equipment used for nonsurgical collection of embryos.

Experimental Procedure

Repeat breeder heifers and cows are being artificially inseminated with proven fertile semen. On the seventh day after insemination an attempt is made to recover the egg, using nonsurgical embryo collection procedures, to determine whether or not fertilization has occurred and if so, whether or not the embryo is developing normally. This procedure will be attempted at least three times for each cow. Figure 1 illustrates the collection catheter which is placed through the cervix and into the uterine horn (Figure 2) on the side where ovulation has occurred. The site of ovulation is determined by palpation of the ovaries per rectum to detect the presence of the corpus luteum (CL). The balloon near the tip of the collection catheter is inflated with air and collection fluid (Dulbecco's Phosphate Buffered Saline plus 5% heat treated newborn calf serum and 100 units/ml penicillin, 100 micrograms (μg)/ml streptomycin and 0.25 micrograms

Figure 4. Microscope used in searching for embryos.

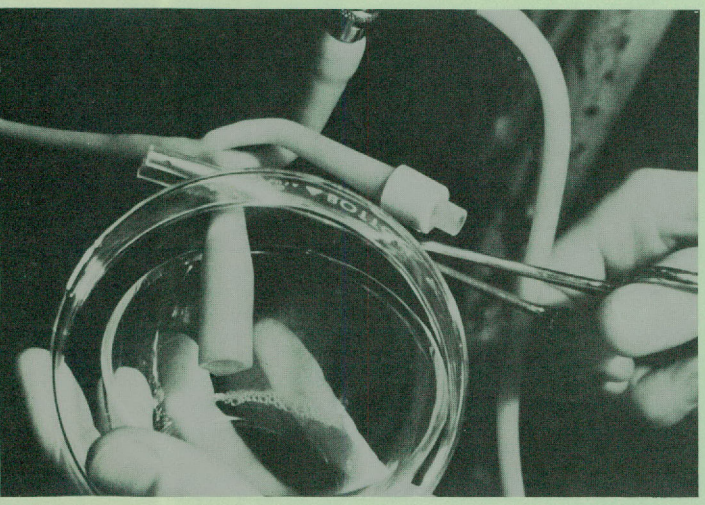

Figure 3. Collection of the fluid as it returns from the uterus.

Figure 5a. An unfertilized bovine ovum.

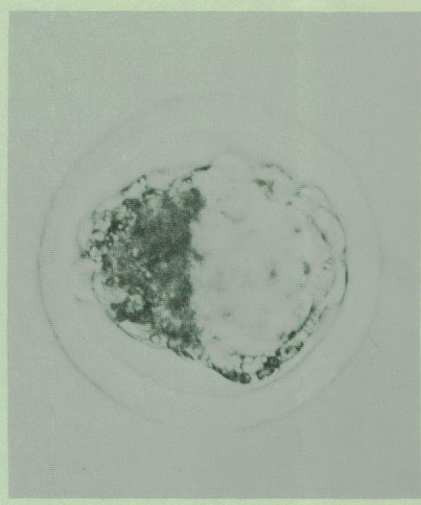

Figure 5b. A bovine blastocyst (7 day embryo).

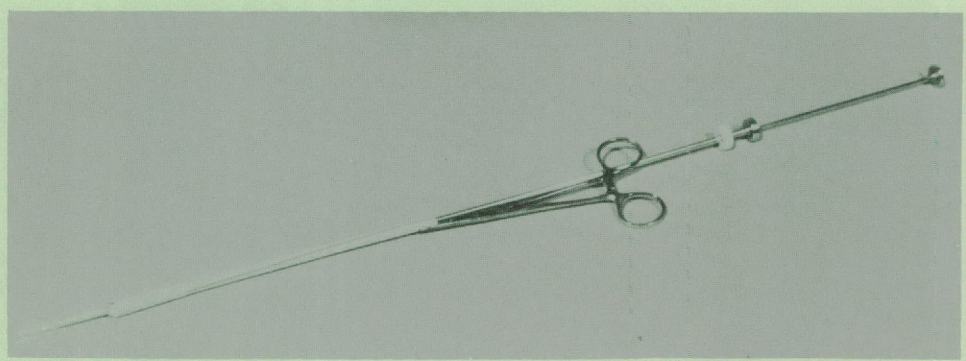

Figure 6. The equipment used for nonsurgical transfer of embryos.

(μg)/ml fungisone) is introduced into the tip of the uterine horn. The uterine horn is gently massaged, and the collection fluid is allowed to flow out through the catheter into collection bowls (Figure 3). The collection fluids are examined using a dissecting microscope (Figure 4), which is set to magnify the eggs or embryos approximately 15 times. After the egg (embryo) has been located, it is examined under higher magnification to determine whether fertilization has occurred and development is proceeding normally. It may be necessary to fix and stain the egg for detailed microscopic examination to differentiate between an egg which is unfertilized and one which has been fertilized but has undergone early embryonic degeneration. Figures 5a and 5b illustrate one unfertilized egg and a normally developing 7 day cow embryo, respectively. It should be realized that there is considerable variation in each of these structures between cows.

Normal embryos from proven fertile cows are being transferred to repeat breeder females to assess the ability of the repeat breeder (host) to maintain an established pregnancy. Usually the embryos are deposited into the host uterus by nonsurgical procedures, but for those animals in which the cervix cannot be penetrated, a surgical procedure is used. Figure 6 illustrates the equipment used for nonsurgical embryo transfer. It is the same equipment used for insemination of semen stored in straws (referred to here as the transfer catheter). In addition, a sheath made by taping a piece of wrapping paper over the end of a soda straw is placed over the transfer catheter to protect it from contamination as it is passed through the vagina. After entering the cervix, the transfer catheter is pushed through the wrapping paper tip of the sheath, through the cervix and into the uterine horn on the side where ovulation has occurred (as shown by the presence of a CL). The embryo is placed as far into the uterine horn as possible without causing excessive trauma. This aspect of the procedure requires considerable practice to develop proficiency. A normal embryo will be transferred to each infertile female during three separate estrous cycles unless pregnancy is maintained from a previous transfer. For this study, embryos are being collected and transferred in fertile cattle to establish the expected or control rate of success.

Results and Discussion

To date, 4 of 15 infertile females have yielded good quality embryos, suggesting that fertilization failure was not the reason for their infertility. Five of the 15 infertile females yielded at least 1 unfertilized egg and no embryo, suggesting that fertilization failure might explain their infertility. However, no eggs nor embryos were recovered from 6 of the 15 infertile females. Failure to recover an embryo in three cases was caused by inability to pass the collection catheter through the cervix. Two of the six were found to have obstructed oviducts, and no apparent reason was found for collection failure in two of the remaining infertile females.

Eight of the 12 control (fertile) females yielded good quality embryos. One of the fertile females yielded two unfertilized eggs, and no eggs or embryos were obtained from the remaining three control cows. Two of these expressed heat and were inseminated, but corpora lutea were not detectable on the ovaries per rectum. The reason for collection failure on the remaining control female is not apparent.

Eighteen embryos have been transferred to 12 of the infertile cows and 2 pregnancies have been obtained. One of these pregnancies was in a cow which had yielded no eggs nor embryos from the previous collection attempts and the other had yielded 2 embryos.

Twelve embryos have been transferred to nine of the fertile (control) females and five pregnancies have been obtained. Four of the five pregnant, fertile females had produced good quality embryos during the collection trials, and the remaining pregnant female had yielded neither eggs nor embryos during the collection trials.

Acknowledgment

This study is being supported by SEA-CR Animal Health funds through the Texas Agricultural Experiment Station and the Texas A&M University College of Veterinary Medicine.

PR-3918

Effect of Abomasal Infusion of Propionate on the GnRH Induced Luteinizing Hormone Release in Prepuberal Heifers

L. M. Rutter, R. D. Randel, G. T. Schelling and D. W. Forrest

Summary

Twelve propuberal Brangus heifers (8-10 months of age; 370-435 lb) were fitted with abomasal cannulae and assigned to one of two infusion treatments: 1150 ml of water/day (C heifers) or 200 ml of propionate (9 percent digestible energy) + 950 ml of water (P heifers). The heifers were individually fed 10 lb of a ration consisting of cottonseed hulls, corn, soybean meal, molasses, DiCal-P, salt and vitamins A, D and E/day. The infusion treatments were delivered via a peristaltic pump from day 0 through day 25 (day 0 = onset of infusion treatment) of the trial, and infusion treatments were switched on day 24 of the

trial. The heifers were given two 100 micrograms (μg) GnRH challenges, administered intramuscularly 6 hr apart, at three periods of the trial: Period I - 24 hr after the onset of the infusion treatment; Period II - 21 to 23 days after the onset of the infusion treatment; and Period III - 24 hr after the infusion treatments were switched. Blood samples for luteinizing hormone (LH) were collected via jugular cannulae prior to each initial GnRH injection and thereafter at 10 min intervals for 12 hours. At approximately 6 hr postprandial, an additional blood sample was collected during each period for determination of plasma glucose levels. No difference was found in the magnitude of the LH surge between C or P heifers at Period I, although P heifers had a longer duration of the LH surge after the first GnRH injection than did C heifers ($P<.05$).P heifers also had a lower concentration of plasma glucose ($P<.10$) than did C heifers. At Period II, P heifers showed a greater LH response to the first GnRH injection than did C heifers ($P<.005$). P heifers also had a higher peak LH concentration and a greater area under the LH curve after the first GnRH injection than did C heifers ($P<.10$). At Period II, P heifers had a higher concentration of plasma glucose ($P<.10$) than did C heifers. At Period III, P to C heifers maintained a greater LH response to both the first ($P<.05$) and the second ($P<.025$) GnRH injection and also had a longer duration of the LH surge after the second GnRH injection ($P<.05$) than did C to P heifers. There was no difference in plasma glucose levels between C to P and P to C heifers at this period. It is concluded from these data that abomasal infusion of propionate enhances the ability of the prepuberal heifers to respond to a GnRH challenge.

Introduction

Monensin sodium is a feed additive which causes a shift in the rumen volatile fatty acid (VFA) concentrations such that the molar percentage of propionate is increased at the expense of acetate and butyrate (10, 11). Hertelendy *et al.* demonstrated that propionate infused intravenously at physiological levels stimulated insulin secretion in sheep. At high levels, propionate infusion stimulated both insulin and growth hormone secretion (1). Feeding a monensin-containing or a high concentrate diet to prepuberal heifers has been shown to result in a decrease in age and weight at puberty (5, 6). After consumption of a monensin-containing diet for two weeks, prepuberal heifers also exhibit an increase in ovarian size and, when challenged with follicle stimulating hormone and human chorionic gonadotropin, exhibit an increase in ovarian weight, an increaed weight of follicular fluid and stroma, a greater number of ovulation sites/heifer, a greater number of corpora lutea/heifer and an increase in luteal progesterone/heifer compared to heifers receiving no dietary monensin (2). In addition, prepuberal monensin-fed heifers have also shown an enhanced ability to release LH in response to an exogenous gonadotropin releasing hormone (GnRH) (8) or estrogen (9) challenge compared with nonmonensin contemporaries.

Since the major objective of this study was to determine if propionate was mediating the effect on the pituitary's responsiveness to GnRH seen with dietary monensin or a high concentrate diet, abomasal infusion of propionate was chosen to avoid changing the ruminal VFA concentrations between control and propionate treatments. Williams *et al.* (14) had shown that the abomasum was capable of absorbing VFA's at rates comparable to that of the reticulorumen. Therefore, the objectives of the current study were (1) to determine if abomasally infused propionate can affect the ability of the prepuberal pituitary to respond to an exogenous GnRH challenge, and (2) to determine whether a propionate effect can be initiated and abolished within a short period of time.

Materials and Methods

Twelve prepuberal Brangus heifers (8-10 months of age; 370-435 lb) were paired by presurgery weight and randomly assigned to receive either water (C) or propionate (P) infusion. Abomasal cannulae were implanted 21 to 22 days prior to the start of the infusion treatment, and following a 10 day postoperative recovery period, the heifers were placed in stanchions and individually fed 10 lb of 45 percent cottonseed hull, 35 percent ground corn, 15 percent soybean meal, 3.5 percent dried cane molasses, and 1.5 percent dicalcium phosphate, trace mineral salt and vitamins A, D and E ration/day.

From day 0 through day 25 (day 0 = start of infusion treatments), infusions were delivered via a peristaltic pump at a rate of 1150 ml/day of either water (C heifers) or 200 ml propionate plus 950 ml water (P heifers). The amount of propionate infused was calculated to be approximately 9 percent of the total daily digestible energy for a 330 lb heifer. This level of propionate was chosen based on reported ruminal propionate production rates in sheep and in steers fed a hay diet supplemented with monensin (4, 13). Infusion treatments were switched (i.e., C switched to P and P switched to C) on day 24 of the trial.

To determine the pituitary's ability to release LH, two 100 μg GnRH challenges were injected intramuscularly 6 hr apart at each of the following bleeding periods of the trial: Period I - 24 hr after the start of infusion treatment; Period II - after 21 to 23 days on infusion treatment; and Period III - 24 hr after the infusion treatments were switched. Blood samples were collected via jugular cannulae prior to the first GnRH injection at each period and thereafter at 10 min intervals for the next 12 hours. The serum was stored at 0 C until assayed for LH using a modification of the double antibody radioimmunoassay described by Niswender *et al.* (7). At approximately 6 hr postprandial during each period, an additional 10 ml of blood was collected into heparinized tubes. The plasma was stored at 0 C until assayed for glucose.

Treatment differences in the magnitude of the LH response and differences in plasma glucose levels between C and P heifers were determined by analysis of variance. The individual LH curve characteristics, including peak LH concentration, time to the LH peak, duration of the LH surge and area under the LH curves, and changes in plasma glucose concentration between treatments and bleeding time were compared using the Student's T-test (12).

Results and Discussion

Following each GnRH challenge, both treatment groups exhibited LH surges within 10 min after injection. The magnitude of the LH response to both the first and second 100 μg GnRH challenges was not significantly different between C and P heifers at 24 hr after the onset of infusion treatment (figure 1). Analysis of the LH surge characteristics at Period I by the Student's T-test revealed that the duration of the

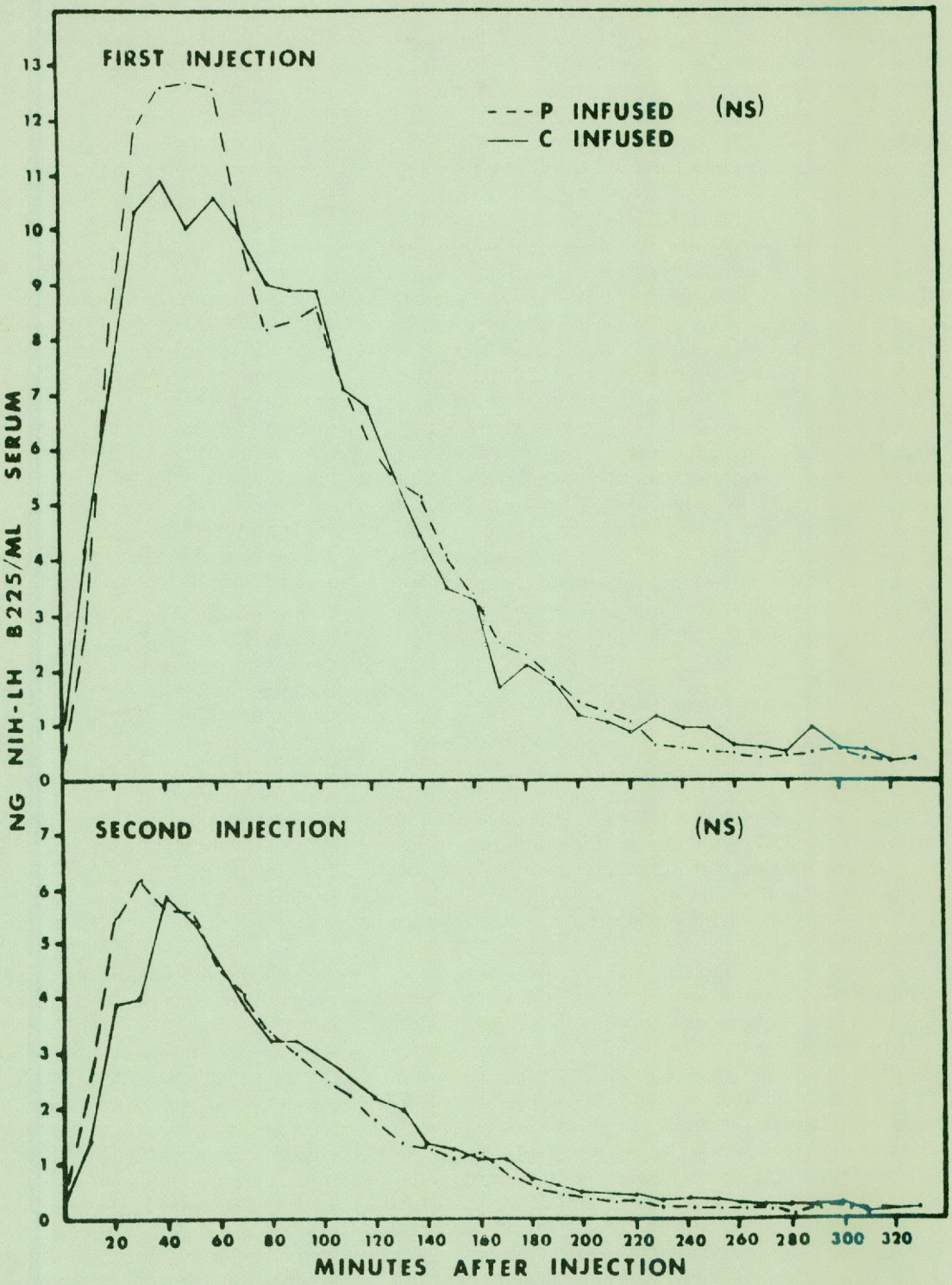

Figure 1. LH response in heifers challenged with 100 μG GnRH previously infused with propionate (P) or water (C) for 24 hours.

LH surge after the first GnRH injection was longer (P<.025) in P heifers than in C heifers (table 1). P heifers also tended to have a higher LH peak concentration, a shorter time to the LH peak and a greater area under the LH curve after both the first and second GnRH injection than did C heifers (P<.10).

After 21 to 23 days on infusion, P heifers showed a greater (P<005) LH response to the first GnRH injection than did C heifers (figure 2). There were no significant treatment differences in the magnitude of the LH response after the second GnRH injection at Period II. There were also no significant differences in the individual LH surge charcteristics between C and P heifers after either GnRH injection, although P heifers again tended to have a higher peak LH concentration and a greater area under the LH curve after the first GnRH injection than did C heifers (table 2).

When the infusion treatments were switched, and the heifers were challenged with GnRh 24 hours following reversal of the treatments (figure 3), the heifers that had previously been receiving propionate

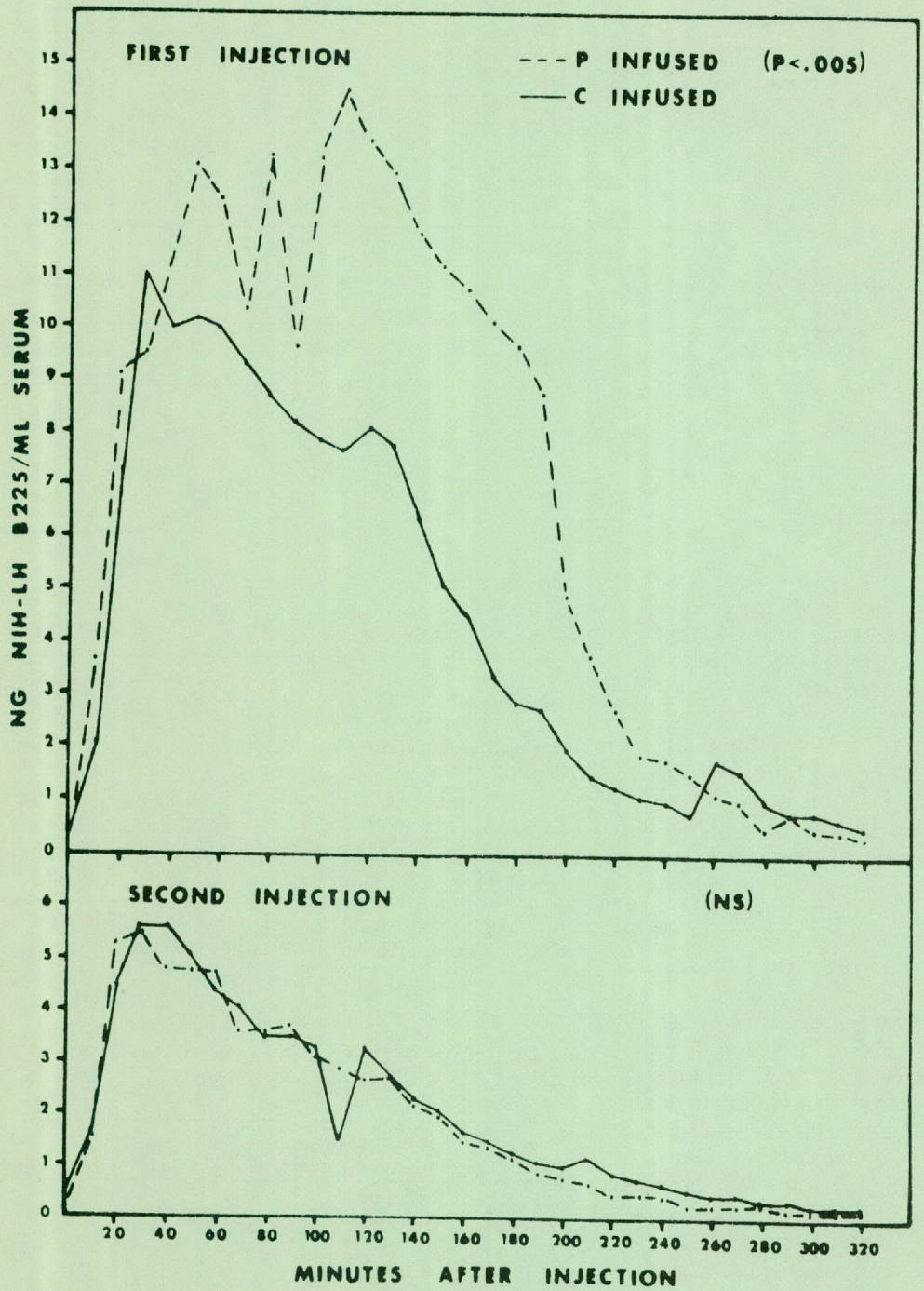

Figure 2. Luteinizing hormone response in heifers challenged with 100 μG GnRH with propionate (P) infused abomasally compared with water (C) after 21 to 23 days of infusion.

TABLE 1. LH CURVE CHARACTERISTICS IN HEIFERS CHALLENGED WITH 100 μG GnRH PREVIOUSLY INFUSED WITH PROPIONATE (P) OR WATER (C) FOR 24 HOURS

GnRH	Treatment	Peak (ng/ml)	Time to peak (min)	Duration (min)	Area under LH curve
1st Injection	C	13.0 ± 3.6	45.8 ± 9.1	196.7 ± 13.1	1275.1 ± 397.2
	P	14.6 ± 1.0	40.3 ± 4.5	246.7 ± 9.2*	1438.5 ± 158.0
2nd Injection	C	6.3 ± 1.5	38.3 ± 7.8	183.3 ± 13.6	538.6 ± 120.2
	P	6.6 ± .7	35.5 ± 7.4	168.3 ± 16.0	545.2 ± 84.3

*P<.025.

TABLE 2. LH CURVE CHARACTERISTICS IN HEIFERS CHALLENGED WITH 100 μG GnRH PREVIOUSLY INFUSED WITH PROPIONATE (P) OR WATER (C) FOR 21 TO 23 DAYS

GnRH	Treatment	Peak (ng/ml)	Time to peak (min)	Duration (min)	Area under LH curve
1st Injection	C	14.2 ± 3.5	52.0 ± 13.9	228.0 ± 15.7	1448.9 ± 456.6
	P	22.6 ± 5.5	64.2 ± 20.1	206.7 ± 14.0	2292.0 ± 917.1
2nd Injection	C	7.1 ± 1.5	45.5 ± 10.8	140.0 ± 22.2	616.2 ± 203.5
	P	7.0 ± 2.1	42.5 ± 10.1	106.7 ± 26.9	593.6 ± 261.2

TABLE 3. LH CURVE CHARACTERISTICS IN HEIFERS CHALLENGED WITH 100 μG GnRH FOLLOWING A 24 HR REVERSAL OF PREVIOUS 21-23 DAY PROPIONATE (P→C) OR WATER (C→P) INFUSION

GnRH	Treatment	Peak (ng/ml)	Time to peak (min)	Duration (min)	Area under LH curve
1st Injection	C→P	7.8 ± 1.5	37.3 ± 3.3	178.3 ± 21.8	551.1 ± 105.8
	P→C	9.1 ± .5	38.5 ± 3.1	191.7 ± 16.2	649.1 ± 79.8
2nd Injection	C→P	4.3 ± .7	28.2 ± 8.8	125.0 ± 7.6	261.5 ± 44.6
	P→C	5.4 ± .8	22.1 ± 3.5	161.7 ± 14.4*	346.2 ± 47.2

infusion for 21 to 23 days (P to C heifers) maintained a greater magnitude of LH release after both the first (P<.05) and the second (P<.025) GnRH injection than did heifers previously infused with water and switched to propionate for 24 hours (C to P heifers). The Student's T-test analysis of the individual LH curve characteristics (table 3) revealed that only the duration of the LH surge was different between the two treatments after the second GnRH injection (161.7 ± 14.4 min for P to C heifers vs 125.0 ± 7.6 min for C to P heifers; P<.05). P to C heifers also tended to have a greater peak LH concentration and a greater area under the LH curve after both the first and second GnRH injection than did C to P heifers (P<.10).

Plasma glucose levels at approximately 6 hr postprandial were higher (P<.10) for C heifers after 24 hr on infusion treatment than glucose levels of P heifers (table 4). Following 21 to 23 days on infusion treatment, however, P heifers had a greater plasma glucose concentration than did C heifers (P<.10). These results indicate that, after adaptation of the metabolic system to the sudden increase in a glucose precursor seen at Period I, P heifers had more circulating glucose and a greater glucose concentration potentially available to target tissues. There was no difference in plasma glucose concentrations between the two treatments at Period III. Therefore, Period III glucose

TABLE 4. PLASMA GLUCOSE LEVELS[a]

Sampling period	Treatment	Glucose (mg/ml)
24 hr after start of infusion (Period I)	C	86.3 ± 5.8[c]
	P	74.1 ± 5.1[b]
21-23 days on infusion (Period II)	C	79.6 ± 4.8[b]
	P	86.9 ± 1.9[c]
24 hr after switch of infusion (Period III)	C→P	75.9 ± 3.6[b]
	P→C	77.0 ± 5.5[b]

[a]Plasma samples were collected at approximately 6 hr postprandial.
[b,c]Means with different superscripts are different (P<.10).

TABLE 5. ANALYSIS OF VARIANCE OF MEAN PLASMA GLUCOSE LEVELS AFTER 24 HR AND 21-23 DAYS ON INFUSION TREATMENTS[a]

	Degrees of freedom	Mean square	F-value
Treatment (T)	1	35.2	0.27
Period (P)	1	54.3	0.42
T × P	1	566.7	4.40*
Error	20	128.9	

[a]Plasma samples were collected at approximately 6 hr postprandial.
*P<.05.

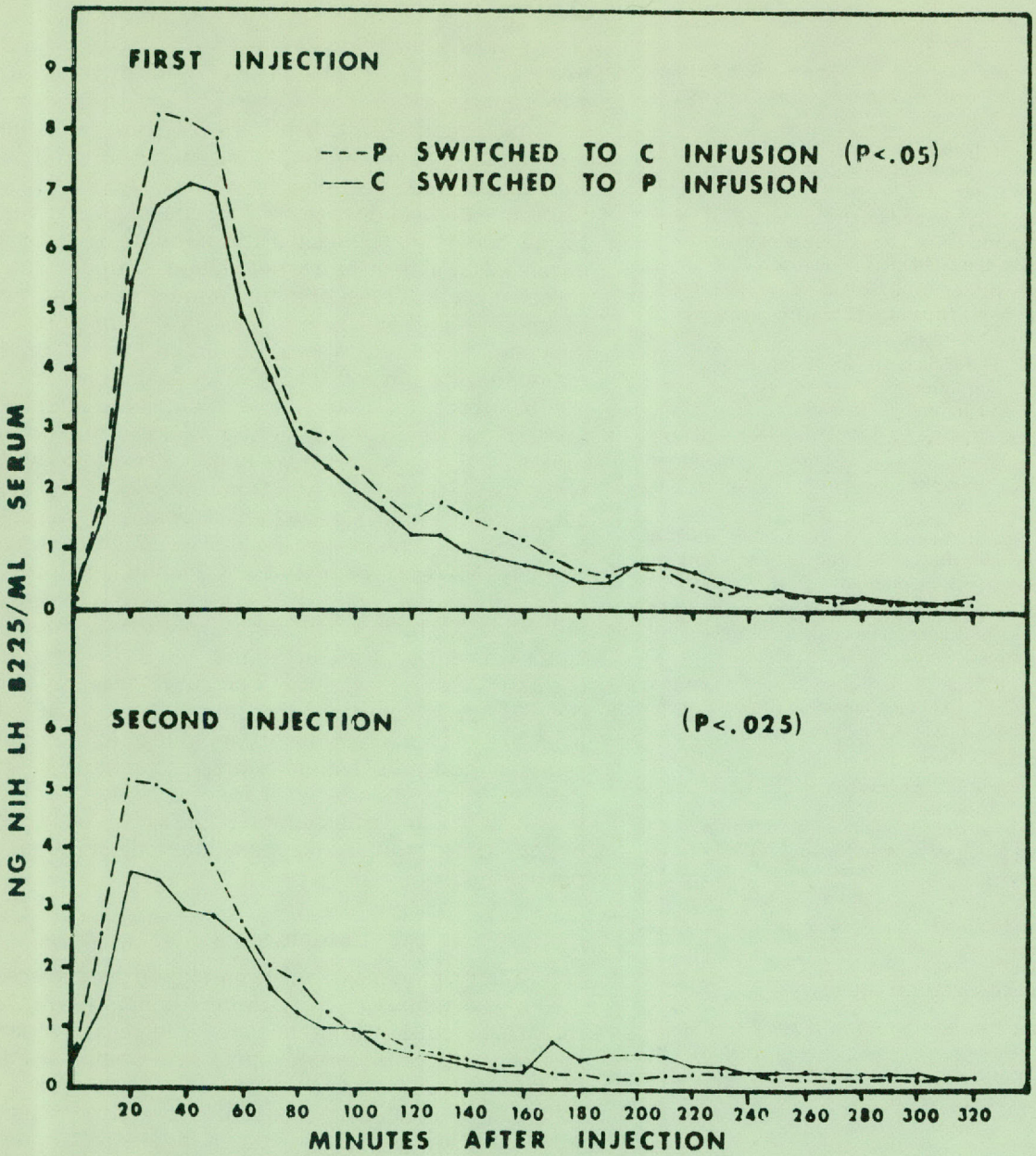

Figure 3. Luteinizing hormone response in heifers challenged with 100 μG GnRH following a 24 hr reversal of previous 21 to 23 days propionate (P→C) or water (C→P) infusion.

values were omitted from the analysis of variance to determine treatment, period and treatment × period interaction. The treatment × period interaction for Period I and II plasma glucose concentration was significant ($P<.05$), indicating a change in glucose concentrations with time (table 5).

In conclusion, these data indicate that the metabolic machinery involved in the ability of the pituitary to respond to GnRH and to subsequently release LH has already begun to undergo a change by 24 hr after the onset of propionate infusion. By 21 to 23 days after the start of propionate infusion, the pituitary is capable of releasing significantly more LH in response to GnRH than pituitaries of heifers receiving water infusion for 21 to 23 days. Moreover, this enhanced ability of the pituitary to release LH is maintained for at least 24 hr after cessation of propionate infusion. Finally propionate infusion for 21 to 23 days results in an increased concentration of plasma glucose.

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PR-3919

Monensin Effects on the Estrogen Induced LH Surge in Prepuberal Heifers

R. D. RANDEL, L. M. RUTTER AND R. C. RHODES III

Summary

The effect of dietary monensin on the luteinizing hormone (LH) surge following estradiol-17β (E2) injection was investigated in prepuberal Simmental × Brahman - Hereford heifers. Ten heifers, weighing approximately 575 lb and at approximately 10 months of age, were equally divided by age and weight into two groups: control (C) heifers received 4 lb/hd/day of a concentrate ration plus Coastal bermudagrass hay *ad libitum*; monensin (M) heifers received the same diet as the C heifers plus 200 mg monensin/hd/day. All heifers were confined in drylots and on their respective diets 14 days prior to E2 challenge. On day 15, all heifers were injected intramuscularly with 5 mg of E2 in a corn oil carrier. Blood samples were collected via tail vessel puncture immediately prior to E2 injection and at 2 hr intervals until 48 hr post E2 injection, processed to yield serum and stored until radioimmunoassayed for LH. Mean serum LH varied ($P<.005$) between C and M and with time after E2 injection. A treatment × period interaction ($P<.10$) indicated timing differences in the LH surge, and when the data were arrayed from the peak of the LH surge, treatment and period effects remained significant with no interaction. Peak LH was 23.1 ± 3.0 ng/ml for M compared to 21.6 ± 4.2 ng/ml for control. Peak LH was reached in 17.2 ± 1.8 hr in M compared to 27.0 ± 6.0 hr in C ($P<.001$). Duration of the LH surge was 8.0 ± .9 hr in M and 4.8 ± 1.6 hr in C ($P<.001$). Area under the LH curve was greater ($P<.001$) in M compared to control. It is concluded from these results that dietary monensin altered the estrogen induced LH surge in prepuberal heifers and that the monensin induced changes in rumen volatile fatty acid (VFA) parameters in some way affects the hypothalamic-pituitary response to estrogens in prepuberal heifers.

Introduction

Dietary monensin has been shown to decrease age and weight at puberty in beef heifers (7, 8), to increase average ovarian size, and to increase ovarian weight, number of corpora lutea and weight of follicular fluid and stroma in response to exogenous follicle stimulating hormone (FSH) and human chorionic gonadotropin (HCG) (4). Randel and Rhodes (10) have also shown that dietary monensin increased peak LH concentration, duration of the LH surge and the area under the LH curve in prepuberal beef heifers challenged with exogenous gonadotropin releasing hormone (GnRH). Barnes *et al.* (1) and Staigmiller *et al.* (14) have shown that the hypothalamic-hypophyseal mechanism responsible for estrogen-induced LH release becomes functional long before puberty is attained in beef heifers. Therefore, in an attempt to further elucidate how an alteration of rumen VFA production affects puberty, the objective of the present study was to determine the effect of dietary monensin upon the estrogen induced LH surge in prepuberal heifers.

Materials and Methods

Ten prepuberal Simmental × Brahman-Hereford heifers, weighing approximately 575 lbs and at approximately 10 months of age, were equally divided

by age and weight into two groups. The control (C) group received 4 lb/hd/day of a concentrate ration consisting of a 3:1 ratio of ground milo to cottonseed meal plus Coastal bermudagrass hay free choice throughout the trial. The monensin group (M) received the same ration as the C group plus 200 mg monensin/hd/day. The C and M heifers were confined in drylots on their respective diets 14 days prior to estrogen challenge.

On day 15, all heifers received an intramuscular injection of 5 mg E2 suspended in a corn oil carrier. Blood samples were collected via tail vessel puncture immediately prior to E2 injection and at 2 hr intervals until 48 hr post E2 injection. Serum was harvested and stored at −20 C until analyzed for LH by a modification of the double antibody radioimmunoassay reported by Niswender *et al.* (9).

Serum LH patterns after E2 injection were analyzed by analysis of variance and means between M and C heifers were compared with the student's T-test (16).

Results and Discussion

Estradiol-17β has been shown to consistently elicit an LH surge when administered to prepuberal heifers with peak values, ranging from 11 to 100 ng/ml (6, 12, 13, 14), obtained within 12-14 hr and lasting 6-8 hr (14). Similarly, in the present study 5 mg E2 induced an LH surge of 21.6 ± 4.2 ng/ml (C heifers), 23.1 ± 3.0 ng/ml (M heifers) in prepuberal heifers fed either 0 or 200 mg monensin. There were, however, marked differences in the characteristics of the E2 induced LH surge between the two dietary regimes (figures 1 and 2). Mean serum LH varied with time after injection between C and M heifers ($P<.005$) and a treatment × period interaction ($P<.10$) indicated some timing differences in the LH surge (figure 1). When the data were arrayed from the peak of the LH surge (figure 2), treatment and period effects remained significant with no interaction. When specific parameters of the LH surge were compared between treatment groups (table 1), M heifers showed an earlier LH peak ($P<.001$), a longer duration of the LH surge ($P<001$), a greater area under the LH curve ($P<.001$), and tended to have a higher peak LH concentration.

The data from this study indicate that the positive feedback mechanism responsible for the E2 in-

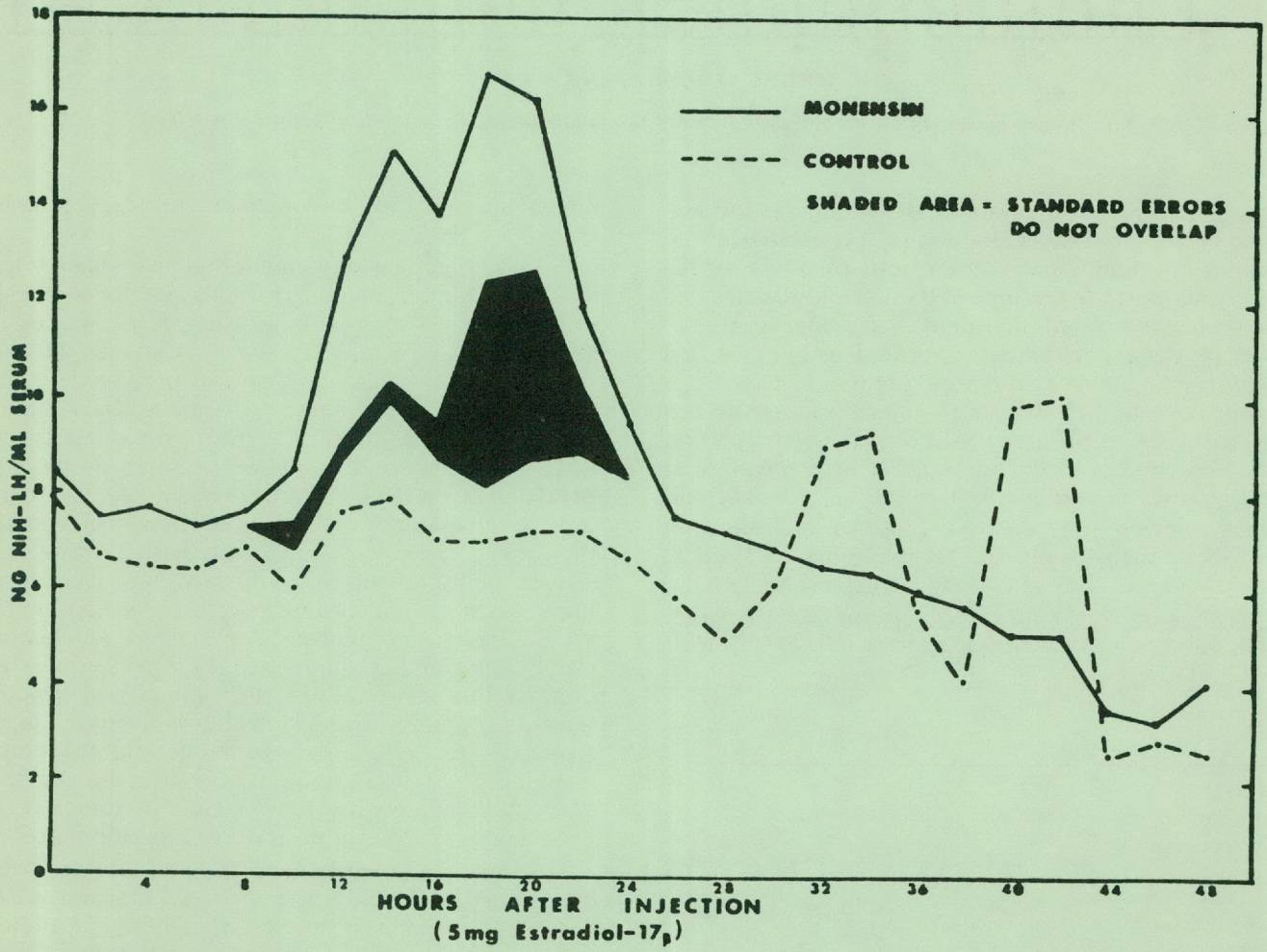

Figure 1. Effect of dietary monensin upon the estrogen induced luteinizing hormone surge in prepuberal heifers.

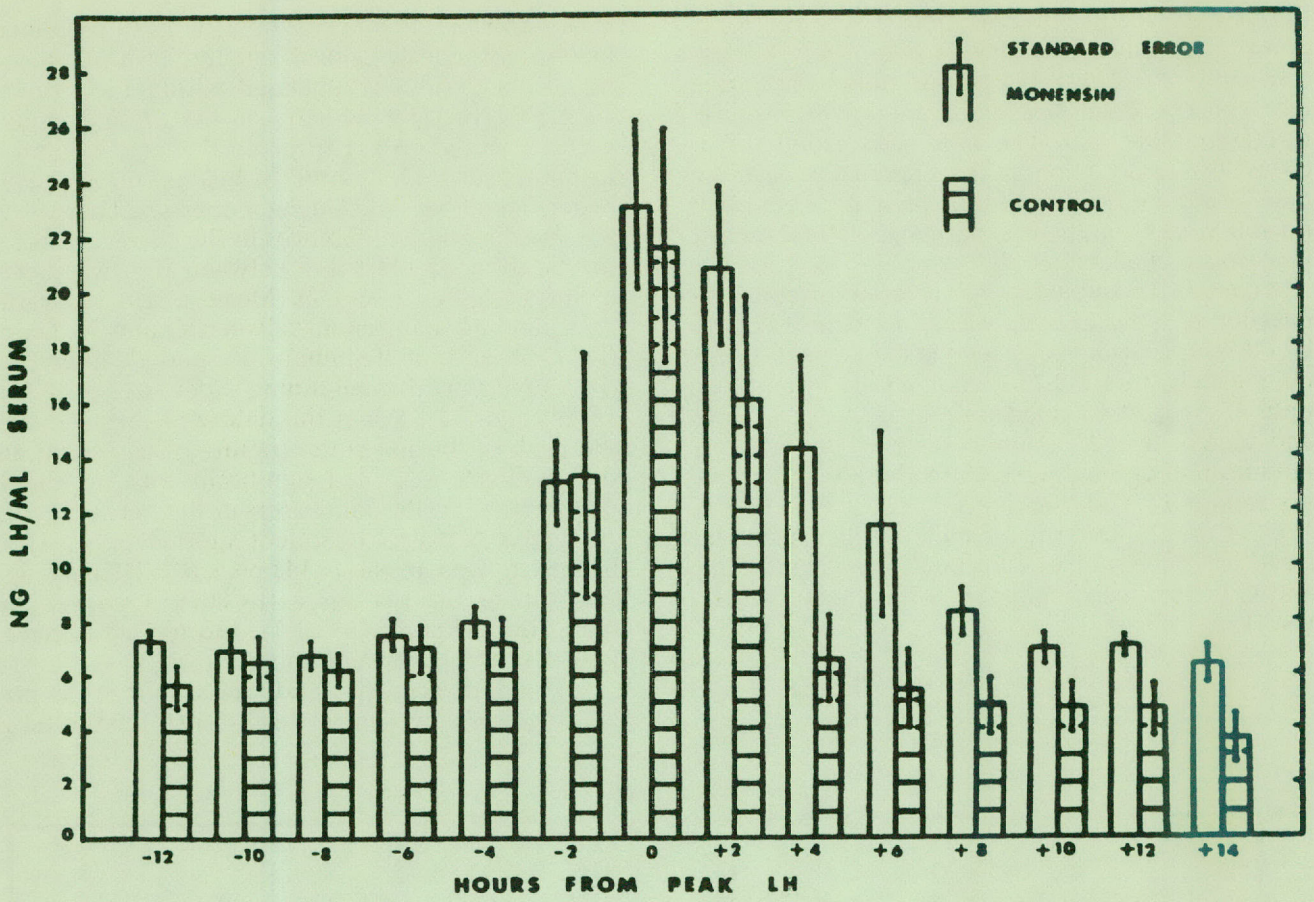

Figure 2. Effect of dietary monensin on the estrogen induced luteinizing hormone surge in prepuberal heifers.

duced LH surge in prepuberal heifers, operational long before puberty is attained (2, 14), is affected by monensin. Additionally, the results obtained in this study support the findings of Randel and Rhodes (10) who suggested that alteration of ruminal fermentation by dietary monensin appeared to enhance the pituitary's capability to release LH in response to an exogenous GnRH challenge. Since monensin has been shown to primarily affect rumen fermentation by increasing bacterial production of propionate at the expense of acetate and butyrate (5, 11), it would seem plausible to suspect that an alteration in metabolic pathways is causing the observed effect of monensin at the hypothalamic-pituitary-gonadal axis.

TABLE 1. EFFECT OF DIETARY MONENSIN ON THE ESTROGEN INDUCED LUTEINIZING HORMONE SURGE IN PREPUBERAL HEIFERS.

Parameter	Monensin	Control ($\bar{x} \pm SE$)	
Peak LH (ng/ml)	23.1 ± 3.0	21.6 ± 4.2	
Time of peak LH (hr)	17.2 ± 1.8	27.0 ± 6.0	(P<.001)
Duration of surge (hr)	8.0 ± .9	4.8 ± 1.6	(P<.001)
Area under the curve (arbitrary units)	1413 ±160	1078 ±53	(P<.001)

There is general agreement that propionate is the single most important substrate for glucose synthesis in ruminants. Using isotope dilution techniques in sheep, Steel and Leng (15) reported that only 40 to 60 percent of the propionate carbon produced in the rumen is converted to glucose. The metabolic fate of the remainder of the carbon from propionate is unknown. The effect of increased ruminal propionate production, either by increasing the concentrate:roughage ratio or by feeding monensin, on reproductive parameters may be mediated through increased energy availability or changes in concentrations of metabolic hormones such as insulin (2, 17,18). The effect of increased animal propionate may also be mediated through changes in concentrations of reproductive hormones such as LH and progesterone (3) and/or through changes in target organ sensitivity to endogenous or exogenous hormonal stimulation (4, 10). Further investigation, however, is warranted to ascertain how a shift in rumen VFA production is affecting reproductive performance.

Although the mechanism of action has not been determined, this study demonstrated that monensin induced changes in nutritive parameters has altered the hypothalamic-pituitary response to estrogens in prepuberal heifers.

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Cloprostenol and Cloprostenol + HCG Effects on Corpora Lutea and Serum Progesterone in Brahman Cows

D. R. Hardin and R. D. Randel

Summary

Two independent trials were conducted to evaluate 1) the effect of the prostaglandin analog-cloprostenol (CLP; ICI 80996) on subsequent corpus luteum size and progesterone content and 2) the effect of CLP and CLP followed by HCG (1500 IU) at estrus on daily serum progesterone levels in Brahman cows.

In the first trial, cows were assigned as untreated controls (n = 8) or to receive 500 μg CLP intramuscularly on day 8-12 postestrus (n = 9). Corpora lutea (CL) were removed surgically and weighed on day 13 after the spontaneous or CLP induced estrus. CL progesterone also was monitored. In a second trial, cows were assigned as untreated controls (n = 15), to receive 500 μg CLP on day 9, 10 or 11 postestrus (n = 10), or to receive CLP as above, plus 1500 IU HCG 12 hr after the CLP-induced estrus (n = 10). Daily blood samples were collected from all cows from day 2 postestrus through the second estrus, thus encompassing the period of CL development and regression.

The data generated in Trial 1 indicated that CLP depressed CL weight (2.7 vs 4.7 mg; $P<.05$) and CL progesterone content (220.88 vs 367.43 μg; $P<.05$) as compared to untreated controls. Serum progesterone during the time period corresponding with CL development was lower ($P<.05$) in CLP-treated cows in Trial 2. The most distinct reduction occurred from day 7 through 10. Postestrus treatment with 1500 IU HCG appeared to increase CL steroidogenic capacity, however, a significant ($P>.05$) difference was not detected between CLP + HCG and either the CLP or control groups.

Introduction

The potential benefits offered by control of the estrous cycle with $PGF_2\alpha$ are numerous. The advantages of controlled breeding are the subject of several review articles. However, the economic feasibility of a controlled breeding program is initially dependent upon the response of the animals to $PGF_2\alpha$ and secondly on the conception rate of the synchronized breeding. The efficacy of $PGF_2\alpha$ or an analog such as CLP has been established. In fact, the hormonal changes which occur following treatment with $PGF_2\alpha$ or CLP have been considered to be normal based on investigations in European breeds. The response of the Brahman-crossbred females to synchronization attempts with CLP has been poor (6, 7) and below the results of contemporary groups of straightbred European breeds (13).

The endocrine signaling process for behavioral estrus and LH release differ between Brahman and Hereford females (4, 11, 12). The possibility exists that the differences that have been demonstrated may be responsible for asynchronies in hormone patterns similar to those reported by Hansel and Beal (5) which were indicated as major causes of synchrony failures.

The intensive processing of Brahman females immediately prior to estrus has deleterious effects on the behavioral (6) and endocrine (Randel, unpublished data) changes associated with the periestrous period. The physiological cause-effect relationship has been presumed to be stress/adrenal oriented, but remains relatively undocumented. Until the mechanism for the phenomenon has been established, data collection by intensive sampling of the proestrous Brahman female should be scrutinized closely.

Conversely, the stage of the estrous cycle encompassing luteal development may be monitored by frequent blood sampling without altering the reproductive cycle of the Brahman female (Randel, unpublished data). Therefore, efforts to evaluate the factors responsible for the low response of the Brahman-type female to estrous synchronization attempts with prostaglandins have been confined to the effects on the subsequent cycle.

Human Chorionic Gonadotropin (HCG) has been demonstrated to exert a luteotrophic effect in the bovine by increasing CL size and total CL progesterone (15). The improvement in ovarian CL development and steroidogenic capacity has been presumed to be responsible for the improved pregnancy rates following HCG treatment at breeding (10, 15). The possibility of using the luteotrophic activity of HCG to improve the fertility response of the Brahman female to synchronization with prostaglandins seemed realistic.

Hence, in addition to evaluating the effects of CLP on CL weight, CL progesterone content, and daily serum progesterone, the following studies were designed to determine if HCG could affect the luteal progesterone production during the CLP-induced cycle.

Experimental Procedure

Multiparous, nonlactating Brahman cows served as experimental animals. Estrus was detected at least once immediately prior to assignment of treatment groups. Estrous detection was intensified to at least 4 × daily during critical periods and continued at a minimum of 2 × daily throughout the trials. Estrous detection was conducted by visual observation aided by surgically altered bulls equipped with chin-ball marking devices. Estrus was confirmed by the presence of CL detection by palpation *per rectum*.

In Trial 1, cows were assigned to control (n = 8) or CLP (n = 9) treatments. Corpora lutea (CL) were removed on day 13 after either the second spontaneous estrus or the CLP induced estrus. CL were removed by exposure of the CL bearing ovary through a paralumbar incision. CL weights were recorded immediately after removal.

In Trial 2, animals were assigned to either control (n = 15), CLP (n = 10), or CLP + HCG (n = 10) treatment groups. CLP cows received 500 μg CLP on either day 9, 10 or 11 postestrus. CLP + HCG cows received 500 μg CLP as above followed by 1500 IU HCG 12 hr after detection of the CLP-induced estrus. Blood samples were obtained from day 2 through either the subsequent estrus or day 45 whichever occurred earlier.

CL weights and total CL progesterone data were analyzed by analysis of variance (14). Serum progesterone data were pooled over days where no difference in progesterone level was detected and pooled means analyzed by analysis of variance. Pooling was done to increase degrees of freedom for each treatment subgroup and provide a more reliable test.

Results and Discussion

The data collected in Trial 1 indicated that a single luteolytic dose of CLP administered to Brahman cows at midcycle reduced ($P<.05$) weight and total progesterone content of the subsequently developed CL (Table 1). The apparent effect on the steroidogenic capacity of the developing CL was supported by the daily serum progesterone levels observed in Trial 2 (Figure 1), since CL size and peripheral progesterone have been shown (8) to be highly correlated ($r = .89$). The postestrus HCG treatment marginally ($P>.05$) improved the serum progesterone levels above CLP treated Brahman cows.

The impaired development of the subsequent CL and serum progresterone production were similar to the lower progesterone levels of infertile or nonpregnant females reported by Erb *et al.* (3) and Henricks *et al.* (9). These data collectively would suggest that a direct suppressive effect of CLP on the ovary may be responsible for the lower fertility of Brahman-type females (7, 13).

The need for development of normal luteal function at the time of second $PGF_2\alpha$ injection (day 8-10) is a basic premise for the theoretical response in a 10 to 12 day double injection regime. The reduced serum progesterone by day 8 through 10 postestrus, as observed in Trial 2, provides sufficient justification to suspect the impaired CL formation as a causative factor in the poor estrous response of the Brahman-type females to $PGF_2\alpha$ synchronization.

TABLE 1. EFFECT OF CLOPROSTENOL (CLP) ON CORPUS LUTEUM WEIGHT AND PROGESTERONE CONTENT IN BRAHMAN COWS

	Corpus luteum	
Treatment	Weight	Progesterone
CLP	2.70 ± 0.42 g[a]	220.88 ± 38.85 μg[c]
Control	4.71 ± 0.21 g[b]	367.43 ± 38.86 μg[d]

[a,b,c,d]Means ± SE with different superscripts differ ($P<.05$).

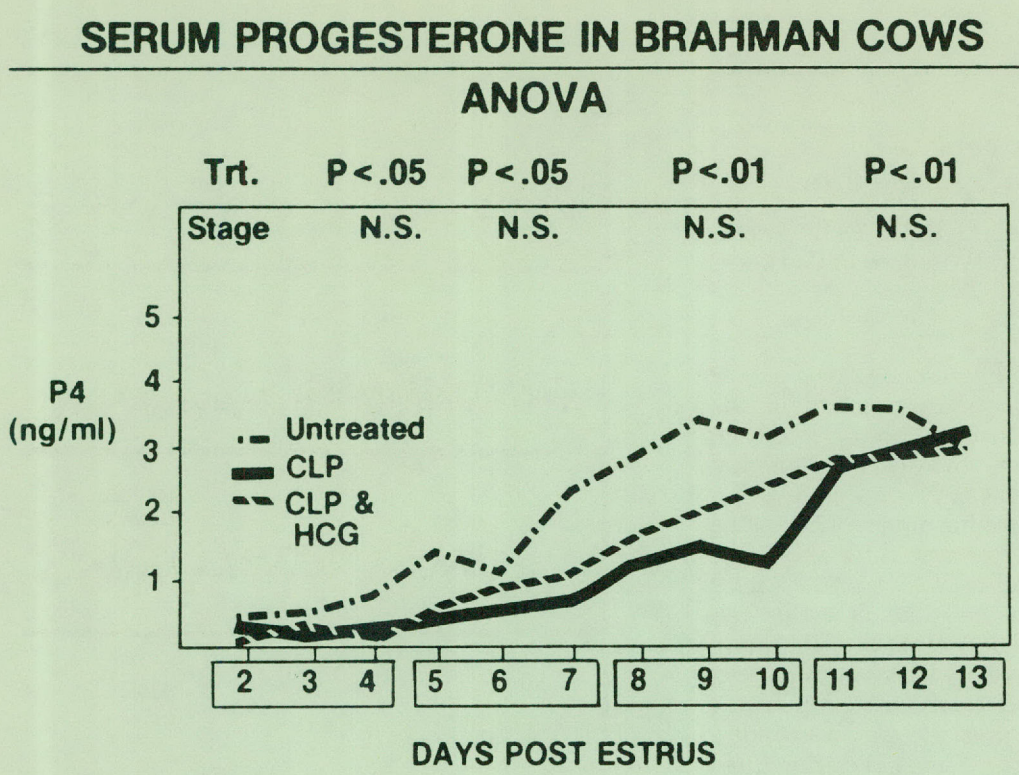

Figure 1. Serum progesterone profiles in control, CLP and CLP + HCG cows.

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Acknowledgments

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PR-3921

Pulsatile Secretion of the Luteinizing Hormone During the Estrous Cycle of the Cow

C. H. Rahe, R. E. Owens, J. L. Fleeger and P. G. Harms

Summary

To efficiently control ovarian function in the bovine, (e.g. estrous synchronization, superovulation) it is essential to understand the physiological regulation of the ovary. It was believed that levels of the gonadotropin (luteinizing hormone - LH) in the blood remained relatively constant throughout the estrous cycle with the exception of a preovulatory peak which occurs around the time of estrus (1). However, preliminary results (2) from our laboratory with frequent (10 min. intervals) blood sampling suggested that LH may actually fluctuate in a pulsatile manner. Consequently, the present study was undertaken to define the pattern of plasma LH during three periods of the estrous cycle of the cow.

Experimental Procedure

Blood samples were collected through an indwelling jugular vein cannula from docile Holstein heifers (17-20 months of age). Samples were obtained at 10 min. intervals for 24 continuous hours, on day 3 (early luteal period), day 10 or 11 (mid-luteal period), and day 18 or 19 of the estrous cycle. Resulting plasma was subsequently analyzed for LH concentration with a validated radioimmunoassay.

Results and Discussion

As shown in Figures 1, 2, and 3, LH fluctuates in a pulsatile manner throughout the estrous cycle. In addition, the pattern also is dependent upon the period of the cycle. During the early luteal period (figure 1), pulses were classified as low amplitude (△LH, 0.3-1.8 nanograms) and high frequency (20-30 pulses/24 hrs), with each cow exhibiting an inherent rhythmic pattern. However, during the mid-luteal period (figure 2), pulses were classified as high amplitude (△LH, 1.2-7.0 nanograms) and low frequency (6-8 pulses/24 hrs) without an inherent rhythmic pattern. Throughout the preovulatory surge (figure 3), LH also fluctuated in a pulsatile manner, with a frequency more like the early luteal than the mid-luteal period. Amplitude of the pulses was greater during the ascending than during the descending period of the surge.

The data are consistent with the view that the LH pattern is modulated by ovarian steriod hormones. Progesterone, an ovarian hormone which is elevated during the mid-luteal period, may reduce the frequency and increase the amplitude of the pulses.

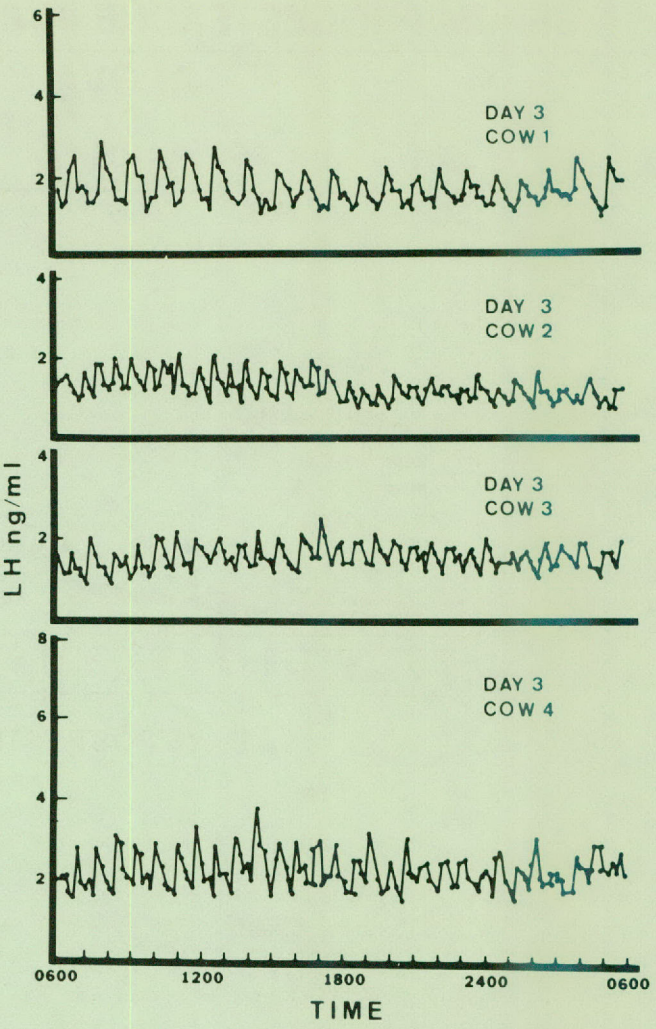

Figure 1. Pattern of plasma LH concentration on day 3 of the estrous cycle (early luteal).

The physiological role of plasma LH pulses on ovarian function in the cow is presently unclear. However, Wildt *et al.* (3) reported in prepubertal monkeys that pulsatile patterns of plasma LH at hourly intervals resulting from administration of luteinizing hormone-releasing hormone, the hypothalamic hormone which releases pituitary LH, stimulated reproductive function. Such results suggest a possible physiological function for the pulsatile fluctuation of LH. Consequently conditions (e.g. stress) that appear to interfere with the pulsatile pattern (unpublished observations) may reduce reproductive efficiency. Under such conditions the administration of luteinizing hormone-releasing hormone to induce LH release in a pulsatile manner may restore reproductive function.

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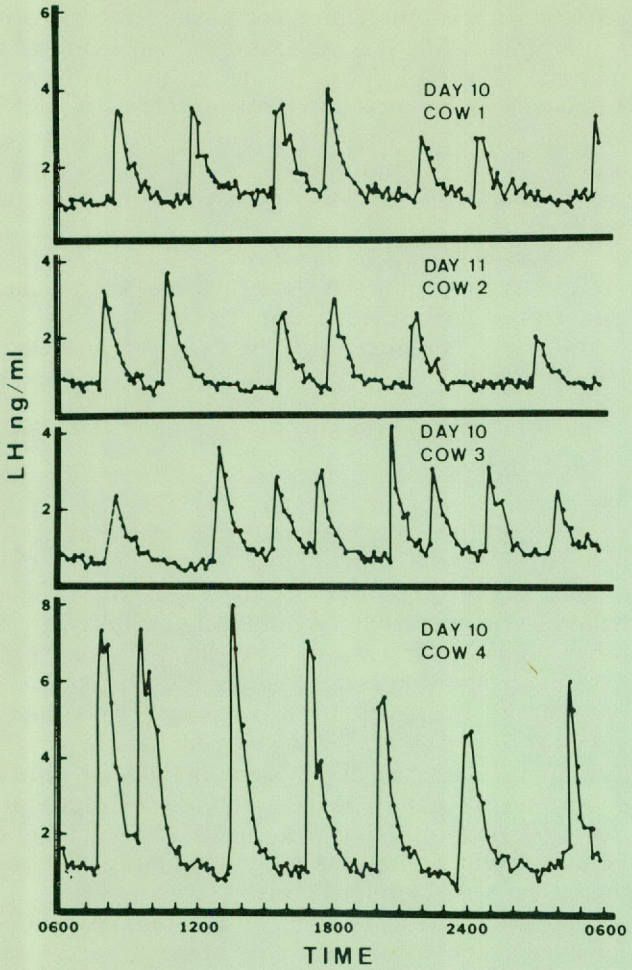

Figure 2. Pattern of plasma LH concentration on day 10 or 11 of the estrous cycle (midluteal).

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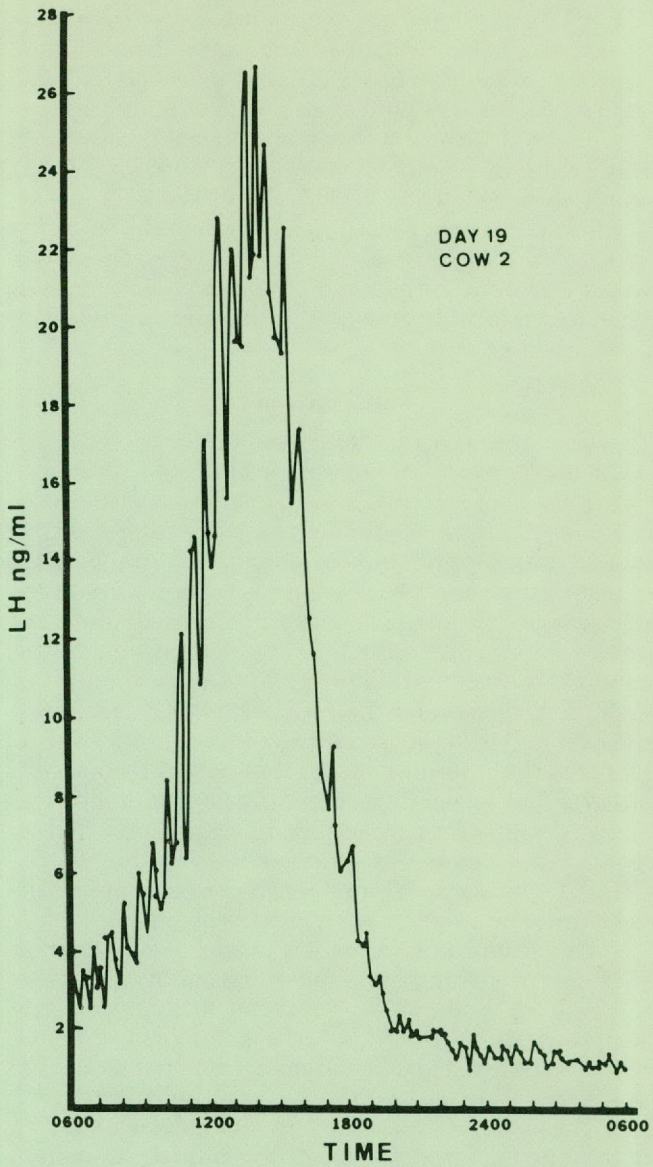

Figure 3. Preovulatory surge of LH on day 19 of the estrous cycle in cow 2.

PR-3922

Seasonal Variation in Seminal Parameters and Libido of Angus and Brahman Bulls

D. R. HARDIN, P. J. CHENOWETH, T. H. FRIEND AND R. D. RANDEL

Summary

Semen samples collected via electroejaculation and libido scores were evaluated at 28-day intervals on nine Angus and nine Brahman bulls. All bulls were postpuberal and determined to be physically sound. The objective of the study was to evaluate the influence of season (spring, summer, fall and winter) and breed (Angus and Brahman) on libido and selected seminal parameters. Libido was scored on replicated tests of randomly paired bulls using nonestrous cows in service crates. Semen samples were evaluated for volume, sperm concentration, sperm motility, sperm abnormalities, live sperm and total live normal sperm.

Angus bulls had higher ($P<.05$) mean ejaculate volume (7.8 vs 5.8 ml), sperm cell concentration (473 vs 433 x 10^6/ml) and libido scores (4.4 vs 2.5) than Brahman bulls. Mean ejaculate volumes were higher

(P<.05) during fall (Sept-Nov) and winter (Dec-Feb) than spring (March-May) and summer (June-Aug) in Angus (7.8, 7.6 vs 6.6, 6.8 ml) and Brahman (6.3, 6.2 vs 5.2, 5.4 ml). Mean sperm concentrations were higher (P<.05) during summer and fall than winter and spring in Angus (498, 499 vs 438, 457 x 10^6/ml) and Brahman (460, 462 vs 397, 413 x 10^6/ml). Total live normal sperm increased (P<.05) from spring to summer, peaked in the fall and declined (P<.05) in the winter for both Angus and Brahman. Libido scores remained relatively constant throughout the year for both breed groups.

Introduction

The optimum time to calve beef cows is during the season of maximal forage production. The nutritional needs of the cow are approximately doubled at calving and these needs must be met before the cow will rebreed. Spring and summer are natural periods of peak forage growth, however, summer-born calves perform poorly in most areas of Texas. If the cow herd calves in the spring, a high proportion of the cows must breed back during the summer months. A great deal of research has suggested that fertility of the beef bull is depressed during the summer season. Reduced bull fertility could be brought about by either impaired spermatogenesis or lower libido. The elevated ambient temperature has been indicated as the principal cause of reduced fertility due to depressed spermatozoal motility, increased abnormalities and various other associated problems.

The scientific information available on seasonal variation of seminal parameters has shown conflicting results, while libido appeared to fluctuate little with season changes. Researchers in Florida (1) have reported that seasonal changes in semen characteristics were influenced by the breed of bulls tested.

The research presented here was conducted to determine the effect of season on seminal parameters and libido of Angus and Brahman bulls in Central Texas.

Experimental Procedure

The study was conducted with postpuberal Angus (n=9) and Brahman (n=9) bulls at College Station, Texas from March, 1979 through February, 1980. The bulls were inexperienced in mating interactions and otherwise sound reproductively and structurally. All bulls were maintained in a 1.6 ha (3.5 A) pasture and received 10 kg (22.016 lb) of a concentrate mixture per head per day plus *ad libitum* access to Coastal bermudagrass hay. Internal and external parasites were controlled by a regular treatment regimen.

Semen samples were collected via electroejaculation at approximately 28-day intervals. Progressive motility, spermatozoa concentration, percent primary and secondary abnormalities, ejaculate volume, and percent live spermotozoa were recorded on each ejaculate.

Libido tests were conducted by admitting two bulls into a test area where cows were restrained in service crates. All other bulls were held in an adjacent pen and allowed to observe the activity of the test animals. Each bull was tested twice on one day with a nonestrus cow. The sexual activity of each bull was scored for each 10-minute test. Scores ranged from 0 (no sexual interest) to 10 (two services with additional interest).

Mean values 5 (two mounts) within each breed group were used for statistical analysis. Data collection periods were divided into March-May = spring; June-Aug. = summer; Sept.-Nov. = fall and Dec.-Feb. = winter.

Results and Discussion

The Angus bulls had consistently higher (P<.05) mean values for ejaculate volume (7.8 vs 5.8 ml), sperm concentration (473 vs 433 x 10^6/ml) and libido (4.4 vs 2.5) than Brahman bulls. The limited number of bulls and the high variability between animals may have been responsible for undetected differences in other parameters measured. Angus bulls resulting from a long-term, breeding program in the southern area of the U.S. may be less affected by climatic stressors than Angus lines developed in more temporate areas. Koger *et al.* (2) demonstrated a similar environmental-genotype interaction in the reproductive performance of females. Fields *et al.* (1) found Florida Angus bulls to be more complacent to summer stress than Hereford bulls.

Mean ejaculate volume of both breed groups followed a similar trend in being higher (P<.05) during fall and winter than spring and summer (table 1). Mean spermatozoa concentration (sperm conc.) of Angus and Brahman also followed the same seasonal patterns even though there were differences between the two breeds (table 1).

Sperm motility of Angus bulls remained relatively constant while sperm motility of Brahman bulls increased (P<.05) in the summer and fall (table 1). Percent of live sperm of both breeds also increased (P<.05) from spring to summer and declined (P<.05) from fall to winter (table 1). Primary abnormalities of Angus bulls remained essentially constant after increasing (p<.05) from spring to summer (table 1). Primary abnormalities of Brahman bulls were lower (P<.05) in the fall and winter compared to values for the spring and summer. Secondary abnormalities of both breeds dropped (P<.05) from spring to summer and remained constant through the remainder of the year. The higher values in the spring may have been due to a postpuberal lag time. Total live normal spermatozoa (TLNS) for both breed groups again followed the same pattern (table 1) by increasing (P<.05) from spring to summer and summer to fall and then declining (P<.05) in the winter.

There was a significant (P<.05) difference between libido performance of the Angus and Brahman bulls (table 1). The Angus bulls, as a group, displayed more aggressive libido in a more consistent manner than the Brahman bulls.

TABLE 1. EFFECT OF SEASON ON SEMINAL PARAMETERS AND LIBIDO OF ANGUS AND BRAHMAN BULLS

Parameter	Season			
	Spring[a]	Summer	Fall	Winter
Ejaculate volume (ml)				
Angus	6.6± 0.1[b]	6.8± 0.2[b]	7.8± 0.2[d]	7.6± 0.4[d]
Brahman	5.2± 0.2[c]	5.4± 0.1[c]	6.3± 0.2[e]	6.2± 0.3[e]
Sperm Conc. (x 10^6/ml)				
Angus	457 ± 5.7[b]	498 ± 7.5[d]	499 ± 9.0[d]	438 ± 10.8[b]
Brahman	413 ± 1.0[c]	460 ± 8.2[b]	462 ±10.1[b]	397 ± 9.4[c]
Sperm motility (%)				
Angus	68.9± 1.9[b]	68.6± 0.5[b]	70.5± 0.9[b]	69.9± 2.0[b]
Braham	67.2± 2.1[b]	76.7± 1.1[c]	75.9± 1.5[c]	67.3± 1.2[b]
Live sperm (%)				
Angus	71.4± 4.6[b]	81.5± 0.6[c]	77.5± 2.0[bc]	63.8± 2.0[e]
Brahman	71.2± 2.1[b]	80.5± 0.2[c]	75.1± 1.9[d]	63.4± 2.1[e]
Prim. Abn. (%)				
Angus	25.9± 1.5[b]	33.5± 1.4[d]	32.6± 1.9[d]	30.0± 4.1[d]
Brahman	20.7± 0.6[c]	20.8± 0.6[c]	16.0± 0.9[e]	13.9± 1.1[e]
Sec. Abn. (%)				
Angus	11.8± 0.9[b]	6.3± 1.0[c]	4.3± 0.4[c]	7.8± 0.8[c]
Brahman	11.5± 0.9[b]	5.3± 1.0[c]	2.9± 0.4[c]	6.9± 0.7[c]
TLNS (x 10^6)				
Angus	930 ±87 [b]	1147 ±50 [c]	1340 ±21 d	946 ±178 [b]
Brahman	695 ±21 [b]	1139 ±74 [c]	1348 ±61 [d]	848 ±115 [b]
Libido ($\bar{x}$)				
Angus	5.4± 0.7[b]	6.7± 0.2[b]	5.3± 0.3[b]	5.2± 0.5[b]
Brahman	2.5± 0.2[c]	5.0± 0.1[c]	2.9± 0.1[c]	3.2± 0.2[c]

[a] Spring = March-May; summer = June-Aug.; fall = Sept.-Nov.; winter = Dec.-Feb.

[b,c,d,e] Means ± SE within parameter rows with different superscripts differ (P<.05).

The study presented here indicates that Angus bulls were somewhat more susceptible to environmental reduction in semen quality, however, the total number of live normal spermatozoa in both breed groups was higher in summer and fall months. Provided that a beef bull has not been overworked, the fertility should remain satisfactory through the fall season.

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PR-3923

Reproductive and Feedlot Behavior: The Role of the Vomeronasal Organ

C. J. Sherry, W. R. Klemm, R. F. Sis, and L. M. Schake

Summary

This is a continuation study of sexual behavior of cattle as it relates to and is affected by odoriferous chemicals in urine. Detection of these odoriferous chemicals was shown to involve an accessory olfactory system, the vomeronasal organ (VNO). In the current study, two methods for occluding the entrance to the vomeronasal organ were developed. These treatments did not affect feed intake or weight gain of 22 mature Santa Gertrudis steers housed in simulated feedlot conditions. The treatments did cause significant changes in post-treatment social rank. Generally, the high-ranking steers lost rank and low-ranking steers gained rank. Both treatments seemed to make the steers more assertive, since the treated animals gained rank at the expense of the controls. The treatments made the social order more homogeneous. Other studies indicated that the electrical activity of the vomeronasal system seems to be sensitive to pressure changes and urine from cows in estrus.

Introduction

The VNO is part of an accessory olfactory system that seems to be involved in detection of odoriferous chemicals (pheromones). Damage to the VNO caused a decrease in sexual activity in laboratory animals

(3,4). Bulls are known to sample female urine as a means of detecting estrus, and this behavior is mediated, at least in part, by the VNO. One way to determine if the system is sensitive to components of female urine would be to implant an animal with electrodes that contact the surface of the VNO sensory epithelium and to record the potentials that are generated by this system.

The VNO may also be involved in a behavioral aberration known as 'bulling', in which steers are mounted or ridden like cows in estrus. The behavior is disruptive to the herd and occasionally results in death. It is estimated that the economic loss associated with buller behavior is $25 per buller (1,2). A simple, rapid method of preventing buller behavior which would not interfere with eating or weight gain would decrease or eliminate this economic loss. Since riding is a normal component of the sexual activity of the bull, blocking the entrance of the VNO might decrease or eliminate buller behavior in feedlot steers.

Experimental Procedures

Blocking Sensory Input to the VNO.

Using 4 Angus bulls, 12 mixed-breed steers, and 22 Santa Gertrudis steers, two methods for occluding the entrance to the VNO were evaluated. In the first method, plugs made of nylon cord were inserted into the oral openings of the incisive ducts which are located on either side of the incisive papilla on the dental pad. Plugs of various diameters and lengths were evaluated. The second method involved cauterizing the entrance of the incisive duct using a heated stainless-steel rod.

Feedlot Behavior

Daily feed intake of 22 Santa Gertrudis steers was determined using 'Calan' gates, which allow measurement of individual feed intake. These steers were previously ranked with regard to social dominance, in competition for food or water after appropriate deprivation. Each animal was randomly assigned to a treatment (i.e. control, plugged, cautery) and a feeding gate to achieve a homogenous mixture of high and low ranking animals. Feed intake was determined on a daily basis for two weeks, the appropriate treatment applied, and then feed intake was monitored for an additional four weeks. The animals were weighed on two successive days every two weeks during the duration of the experiment.

Vomeronasal Organ Electrical Activity.

Two steers were surgically implanted with cannulae into the VNO via the VNO duct. This was accomplished by making an incision 1 cm from the midline and 1.5 cm caudolateral from the oral entrance to the incisive duct. The cannula consists of a Silastic tube with a 30 gauge Nicrome wire threaded down the lumen. This arrangement allows recording of the electrical activity of the VNO sensory epithelium and introduction of various stimuli (urine, foodstuffs, etc.) to the system.

Results and Discussion

Based on gross dissection of several bovine heads, it was determined that the common duct (from its opening at the incisive papilla to the junction with the VNO duct) was approximately 1.5 cm long. The nasal orifice of the incisive duct is in the ventrolateral surface of the nasal passage, 7.5 cm from the nasolabial surface. The VNO orifice is located 1.5 cm caudolateral to the incisive papilla at the level of the first palatine ridge. The orifice opens into the dorsolateral portion of the incisive duct. The VNO is 1 cm lateral to the midline of the nasal septum and extends caudally for approximately 7.5 to 12.5 cm (i.e. near to or at the level of the first cheek tooth).

The treatments (cautery, plug) did not cause a significant change in feed intake (table 1) or weight gain (table 2) when compared to the controls. Many of the steers experienced major changes in rank; the higher ranked steers tended to lose rank and the low ranking steers tended to gain rank (Fig. 1). The treatments tended to make the steers more assertive, since the treated animals tended to gain rank at the expense of the controls.

Preliminary recordings of the electrical activity of the VNO sensory epithelium indicated that electrical activity of the VNO consists of slow potentials (i.e. electroencephalograph-like activity) and that the system is sensitive to pressure changes in the VNO and to bovine urine from a cow in estrus.

TABLE 1. FEED INTAKE OF STEERS, LBS.

Group	Daily feed intake, ± SD		
	Pre-treatment	Post-treatment	
		1st 2 weeks	2nd 2 weeks
Control (n=3)	22.9±3.6	22.4±9.0	17.2±4.9
Cautery (n=6)	21.6±5.0	22.6±4.4	27.0±4.9
Plug (n=8)	19.9±4.3	19.9±4.7	23.0±4.7

TABLE 2. PERCENT WEIGHT CHANGE FROM INITIAL WEIGHT FOR STEERS

Group	Percent Body Weight Change ± SD		
	Pretreatment	Post-Treatment	
		1st 2 weeks	2nd 2 weeks
Control (n=3)	4.2± .8	5.1±2.7	2.5±2.7
Cautery (n=6)	5.2±2.9	3.3±3.1	3.4±2.0
Plug (n=8)	5.6±4.6	2.9±1.7	3.5±2.2

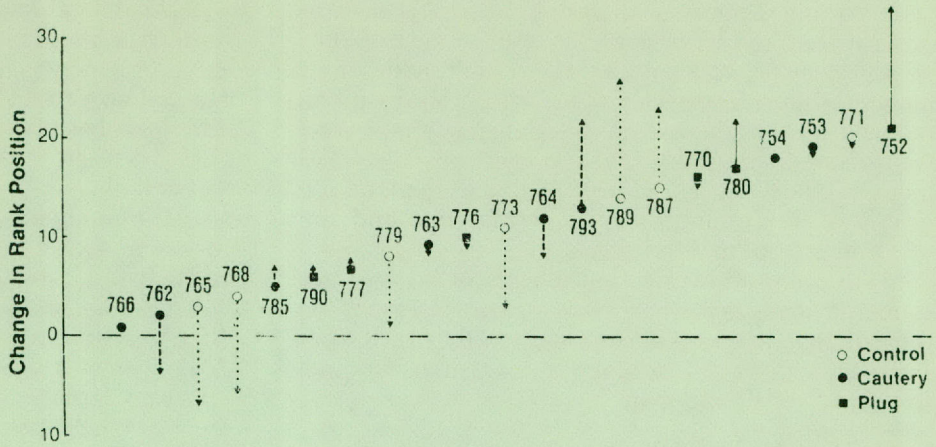

Figure 1. Diagram of the initial rank ordering and the direction and magnitude (arrows) of rank change that were experienced after the 4-week treatment period. To illustrate how to interpret the diagram, consider steer #765; it was originally ranked #3, and after other steers in the herd were plugged or cauterized, it lost 10 rank positions.

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PR-3924

Trace Element Deficiency Effects On Reproductive Function In Beef Cattle: A Review

P. G. LEMIEUX AND D. B. HERD

Summary

Trace elements zinc, copper, manganese, iodine, selenium, cobalt and iron are regarded as dietary essentials. The effects of deficiencies of these elements on reproductive function in beef cattle have been reviewed. Impaired reproductive function can result from either a deficiency of trace elements or from imbalances in the diet. With the exception of zinc, the effect of trace element deficiencies on fertility are manifested primarily in the female. Zinc and copper are the trace elements most likely to be deficient under grazing conditions in Texas.

A zinc deficiency produces a more distinct effect on fertility in the male impairing spermatogenesis and testicular development. A copper deficiency reduces conception rates and increases embryonic and fetal mortality. A manganese deficiency, like a copper deficiency, reduces conception rate but also results in the suppression of estrus. A selenium deficiency will result in lower fertilization rates in the cow. Reproductive failure due to an iodine deficiency is a secondary manifestation of impaired thyroid activity and is characterized by signs similar to those of copper and manganese deficiencies. These include embryonic or fetal loss, poor conception rates and irregular or suppressed estrus. Deficiencies of iron or cobalt are not normally associated with impaired reproductive performance.

Recommended trace element levels for beef cattle breeding herds are given in Table 1. The suggested levels may require adjustment as soil conditions, forage composition or animal performance warrant.

Introduction

Trace elements act primarily as cofactors in enzyme systems in cells (42). Together the 15 known essential trace elements function in a wide variety of physiological processes including those of reproduction. Trace element deficiencies can result from

TABLE 1. SUGGESTED TRACE ELEMENT LEVELS IN THE TOTAL DIET FOR BEEF CATTLE BREEDING HERDS[a]

Trace Element	Level (ppm, dry matter basis)
Zinc	25
Copper	6
Manganese	20
Iodine	.1
Selenium	.1
Cobalt	.1
Iron	30

[a]Adapted from NRC (29). These suggested levels may require adjustment where soil conditions, forage composition or animal peformance warrant.

undersupply, abnormal dietary proportions of various minerals and trace elements or from the presence of antagonistic substances (43). Along with other manifestations, trace element deficiencies result in reduced fertility (9). Where the deficiency is severe, well marked clinical signs make diagnosis and treatment relatively easy. However, trace element deficiencies are commonly mild or marginal and can result in suboptimal fertility.

Naturally occurring deficiencies of seven trace elements have been observed and their effects on reproductive function in ruminants will be reviewed. These elements are: zinc, copper, manganese, iodine, selenium, cobalt and iron.

Zinc (Zn)

Zinc is an essential nutrient for normal growth and health in animals. It functions primarily as a cofactor or constituent of numerous enzyme systems. Although severe clinical Zn deficiencies have been described in cattle under field conditions (25,42), it is not commonly a major problem. However, it is likely that mild or borderline deficiencies exist under Texas grazing conditions. Among the first effects of a mild Zn deficiency is lower reproductive efficiency (25). Spermatogenesis and the development and function of the primary and secondary sex organs in the male, and all aspects of the reproductive process in the female can be adversely affected by a Zn deficiency (42).

Impaired testicular development and function due to a Zn deficiency has been described in bulls as well as rams and goats (42,9). Reproductive performance of Holstein bulls that had received a severely Zn deficient diet (4 ppm) from 8-21 weeks of age was compared to that of bulls fed a Zn adequate diet (40ppm) (30). The deficiency caused a reduction in testicular size, however no difference was observed following a Zn repletion period, indicating that no permanent damage had occurred. No adverse effects were observed on semen characteristics, libido or testes histology. In contrast, testicular growth was impaired and spermatogenesis ceased in ram lambs receiving a Zn deficient diet for 20-24 weeks (44). The manifestation of a Zn deficiency on spermatogenesis appears to depend upon the duration of the shortage. Work with ram lambs has also demonstrated that the Zn requirement is greater for reproductive purposes than body growth (44).

Since Zn functions in enzyme systems, much of the pathological effect of a Zn deficiency is thought to be mediated through enzymatic changes in the animal (25). However, the specific mechanisms involved have not been elucidated. It has been speculated that the function of Zn in ram seminal fluid might be to prevent destruction of spermatozoal DNA by inhibiting DN-ase activity (31). Adequate Zn is essential during the final stage of sperm maturation and also for the survival of the germinalepithelium (44).

Data regarding the effect of Zn on beef cow fertility is limited. However, dairy cows receiving a Zn supplement had a 23 percent higher conception rate than controls (9). Other work with female sheep and goats has also demonstrated an inverse relationship between reproductive performance and Zn status (7,9).

The antagonistic effect of calcium on Zn utilization in swine is well documented, however this relationship between Zn and calcium has not been clearly established for ruminants (25).

Zn is required for normal reproductive function. A deficiency in the male produces a more distinct effect on fertility than in the female. The suggested level of Zn in beef cattle diets is 25 ppm on a dry matter basis.

Copper (Cu)

Copper deficiencies in ruminants are recognized as a major practical problem in many parts of the world including Texas. Deficiencies can result from too little Cu *per se* or from the influences of interfering substances such as molybdenum and sulfur.

A wide variety of clinical symptoms have been described for Cu deficiencies (2,42). Those involving fertility have been associated with the female. Reduced conception rate and embryonic and fetal mortality are the most common symptoms. It is unclear whether reproductive function is affected directly by the lack of dietary Cu or by some general dysfunction produced by a Cu deficiency (9).

Low fertility in cattle grazing Cu deficient pastures was associated with delayed or depressed estrus (42). Reproductive performance of cows has been improved with supplemental Cu, administered orally and by injection (11,13,39,21,16). In one study dairy cows, which had marginally low blood Cu values, were injected with 400 mg of Cu. The conception rate of treated cows was 72 percent compared with 53 percent for the untreated group (16).

No clear relationship between blood Cu levels and reproductive performance is apparent in cows (20), therefore blood Cu does not appear to be a reliable indicator of Cu adequacy for the reproductive function.

Dietary Cu appears to be required for normal reproductive function in the ruminant, however, its precise mode of action is unclear. Furthermore, recommendations of Cu levels required to attain optimal fertility depend upon the molybdenum and sulfur levels of the diet. Mature beef cattle require 4-6 ppm of Cu (dry matter basis) when the molybdenum level of the diet is less than 1.5 ppm (42). In areas where the diet contains high levels of molybdenum and sulfate, the copper requirement may be increased two or threefold (29,42).

Manganese (Mn)

Naturally occurring manganese deficiencies have been demonstrated in cattle, sheep and goats. The expression of a deficiency depends upon a number of

factors, among them the degree and duration of the deficiency and the age and state of production of the animal (42). The Mn requirement for cattle is substantially higher for reproductive functions than for body growth (29).

The principal manifestations of a Mn deficiency on fertility are the suppression of estrus and depressed conception rates. Other manifestations are lower birth weights and an increased incidence of abortions, stillbirths, and fetal deformities (40,42,9). Mature Hereford cows receiving a low Mn diet (16-18 ppm) for 12 months before breeding required an average of four services per conception compared with two for cows receiving a control diet (25 ppm), furthermore all calves born to the low Mn group had bone deformities (32). Calves born to Hereford heifers fed a low Mn diet (13-14 ppm) for 3 months prior to gestation were weak and had difficulty standing compared to calves from heifers receiving the control diet (2l ppm) (15). However, there were no observed differences in the reproductive performance of the heifers in either group. The shorter duration of the deficiency and/or the younger age of the cattle may account for the lack of an effect on reproductive performance. Estrus irregularities, reduced conception rates and effects on the newborn have also been observed in dairy cattle, sheep and goats receiving Mn deficient diets (45,4,28,10).

In dairy cows an interaction between the Mn adequacy of the diet and the calcium to phosphorous ratio has been observed (11,12,13,45,4). High dietary calcium to phosphorous ratios appear to increase the Mn requirement. This has led to the suggestion that dietary Mn levels should be increased 90-120 percent above the normal recommendation when the calcium to phosphorous ratio exceeds 2:1. Beef cows grazing alkaline soils or forages high in Ca may benefit from increased levels of dietary manganese.

No work relating dietary Mn levels to bull fertility has been reported, however, no deleterious effects on fertility or libido were observed in male goats receiving a low Mn (less than 2 ppm) diet, although sperm motility and numbers were reduced (9).

The precise site and mode of action of Mn on reproductive function is unknown (42). It has been suggested that Mn is involved in luteal tissue metabolism and/or activity (9). It also has been suggested that Mn is involved in cholesterol synthesis, thus a lack of Mn would reduce the biosynthesis of cholesterol and ultimately gonadal hormones, with consequent effects on fertility (6).

Mn is required for normal reproductive function in beef cattle. Although severe Mn deficiencies are not a major problem in Texas, borderline deficiencies, particularly due to the interaction of dietary Ca and P, may be of practical concern. The suggested Mn level is 20 ppm of ration dry matter.

Iodine (I)

The primary physiological requirement for iodine is for synthesis of the thyroid hormones, thyroxine and triiodothyronine. Iodine deficiencies occur under certain natural conditions and have an influence on reproductive function. Reproductive failure due to iodine deficiency is a secondary manifestation of impaired thyroid activity and is associated primarily with the female. It is characterized by embryonic or fetal loss, poor conception rates and irregular or suppressed estrus (8,42).

Iodine deficiencies can arrest fetal development at any stage leading to early death and resorption, abortion, and stillbirth or the birth of weak young. The condition is often associated with prolonged gestation and parturition and retained placentas (1,26). Serum protein bound iodine (PBI) levels are a measure of iodine status and subnormal levels in cows have been associated with infertility and a high incidence of aborted, stillborn and weak calves (1). Significant negative correlations between PBI values and interval from first breeding to conception ($-.67$) and services per conception ($-.69$) have also been reported (19).

Field studies in iodine deficient areas have suggested a relationship between iodine supplementation and reproductive performance. In one study a significant increase in first service conception rates and a decrease in the incidence of retained placentas and irregular breeding intervals was obtained with dairy cows receiving supplementary iodine (26). Another study reported improvement in first service conception rate by feeding an organic iodine supplement, beginning 8 to 10 days before the cows came into estrus (23).

The beneficial effect of iodine is believed to involve stimulation of the gonadotrophic hormones (9). Dairy heifers that were thyroidectomized, ceased to exhibit estrus at regular intervals (38,24). An iodine deficient diet fed to dairy cows resulted in an ovulatory estrus caused by disturbance of thyroid and pituitary function. This condition was corrected by the addition of iodine to the diet (37).

Reproductive dysfunction associated with iodine deficiency also has been reported in bulls. Libido and semen quality were adversely affected by the deficiency (42).

Iodine influences reproductive performance through its role in thyroid function. The effect of an iodine deficiency in ruminant fertility is well documented for the female and includes embryonic or fetal loss, reduced conception rates and irregular estrus. The suggested dietary iodine level for beef cattle is .1 ppm on a dry matter basis.

Selenium (Se)

Until 1957, Selenium was regarded only as a toxic element, however, it is now well established as a dietary essential. Selenium deficiencies of practical importance occur in farm animals throughout the world and in much of the United States (14,27,3,42), however it is not normally a significant problem with beef cattle grazing in Texas. Impaired reproductive

performance has been associated with a selenium deficiency (42). However, the effects of selenium supplementation on reproductive function have not been consistent.

The metabolic function of Se is closely linked to vitamin E; therefore, many of the studies which have evaluated the effects of supplemental Se on reproductive function have also included vitamin E. Se and vitamin E function to protect biological membranes from oxidative degeneration. They may also have a role in electron transfer (42). Their specific mode of action in reproductive function is not yet known. The principal active form of Se is the enzyme glutathione peroxidase (GSH-Px). Blood GSH-Px levels are an accurate measure of Se status in the animal.

The effects of selenium and vitamin E alone or in combination on *in vitro* fertilization of ova from beef cows on either a low or an adequate plane of nutrition have been evaluated (36). The fertilization rate was 100 percent for females on an adequate plane of nutrition given a supplement of Se and vitamin E. However, rates of fertilization were lower when the diet was deficient in Se and vitamin E or was below the maintenance requirement for protein and energy.

The effect of Se and vitamin E on the incidence of retained placenta in dairy cows has been evaluated (41,17,18). Se and/or vitamin E reduced the incidence of retained placentas when the incidence of this disorder was high.

Other studies with Se deficient beef cows (34) and dairy cows (17) have failed to show a response in reproductive function to supplemental Se. These apparent inconsistencies could result from a number of factors such as variability in the levels of Se and vitamin E in the diets and the presence of antagonistic substances which could influence the availability of Se and/or vitamin E.

The effects of Se on reproductive function in Angus bulls has been evaluated (35). Sperm cell production and viability were not influenced by selenium supplementation.

Reduced fertility in the female has been associated with a Se deficiency . Other factors such as vitamin E are also involved.

The recommended dietary Se level for beef cattle breeding herds in Texas is .1 ppm on a dry matter basis.

Cobalt (Co)

Cobalt is an essential component of vitamin B-12, which is synthesized by rumen microorganism. Co, in the form of vitamin B-12, is required for the metabolism of propionate, an important step in the energy metabolism of ruminants.

Impaired reproductive function is generally not cited as a manifestation of a Co deficiency (2,42), however some reports have suggested that a Co deficiency impairs breeding performance (9). Cattle receiving a Co supplement required less time for post-partum uterine involution, showed stronger manifestations of estrus, and had higher conception rates compared with untreated cattle. Sheep receiving a Co supplement had greater estrus activity and males had increased sperm counts compared with controls. In a trial with three herds of cattle grazing Co deficient pastures, first service conception rates for the control, a copper supplemented and a copper plus cobalt supplemented herd were 53, 67 and 93 percent, respectively (33).

Although naturally occurring Co deficiencies have been observed, reduced fertility has not been widely associated with this condition. It seems likely that reproductive disfunction when it has been observed is a secondary result of the Co deficiency and its effect on the animals' system. The recommended dietary Co level for beef cattle breeding herds is .1 ppm on a dry matter basis.

Iron (Fe)

Although dietary iron is an essential element in all animals, deficiencies seldom occur in mature ruminants unless they are the result of severe blood loss caused by disease or parasitic infestations (29,42). Serum Fe, zinc, copper and manganese were determined to be significantly higher in regular breeders than repeat breeders (22). This finding probably relates more to the status of the other elements than to Fe *per se*. Bull spermatozoa were found to contain greater Fe content than other reproductive tract fluids (5). How this might relate to reproductive functions is unclear.

The suggested Fe level for beef cattle breeding herds is 30 ppm of ration dry matter.

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Biological Efficiency of Growth

PR-3925

Efficiency of Protein Deposition in Muscle as Measured by Rates of Protein Synthesis and Catabolism

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W. C. ELLIS AND G. T. SCHELLING

It would appear that considerable opportunities exist for improving the efficiency of lean tissue growth in cattle. While muscle tissue possesses great biosynthetic capacity for protein production, the efficiency of protein deposition in growing animals is reduced by continual degradation and resynthesis, or "turnover". Growth of lean tissues is the result of a favorable balance between synthesis and degradation of muscle protein.

Theoretically, increased rates of growth can be achieved (1) by increasing the rate of synthesis, which is energetically expensive, (2) by decreasing the rate of degradation, which is probably energetically less expensive, or (3) some combination of both. Experiments in progress should help identify nutrient patterns which modify both protein synthesis and protein degradation.

Fractional rates of skeletal muscle protein synthesis and degradation were determined for growing rats fed either a gluten, gluten + lysine + threonine or lactalbumin diet. The $[^{14}C]Na_2Co_3$ method of labeling the amino acids aspartate and glutamate was used to label muscle protein. Rates of synthesis and degradation were determined by regressing the natural log of specific (DPM/μ mole) and total (DPM) activity of aspartate and glutamate isolated from gastrocnemius muscle on time. Rates of muscle synthesis (Ks), degradation (Kd), and net synthesis (Ks − Kd) were (percent/day): 5.3, 5.4, −0.1 gluten; 12.0, 9.4, 2.6 (gluten + lysine + threonine); and 9.1, 6.2, 2.9 (lactalbumin), respectively.

Results of this study demonstrated that increased rates of growth observed in animals fed good quality protein (gluten + lysine + threonine or lactalbumin) are not only associated with rapid rates of muscle protein synthesis, but also increased rates of degradation. In the case of the gluten + lysine + threonine treatment, 61 percent of the increase in synthesis was offset by the increased rate of degradation.

The energetic cost of protein synthesis has been calculated to be 0.96 kcal/g based on 4 moles of ATP and 1 GTP/mole of peptide bond, thus the energy cost to synthesize 1 gram of net protein was increased 2.6 fold (from 0.96 to 2.46 kcal) due to the protein turnover that occurred with the gluten + lysine + threonine treatment. Subsequent experiments are aimed towards identifying factors which regulate protein turnover and muscle growth in an effort to improve growth efficiency.

PR-3926

Change in Amino Acid Profile of Ruminally Undegraded Feed Protein

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Optimal gains in beef cattle can not be obtained unless essential amino acids are supplied to the tissues in the amounts needed. Therefore, protein sources should be fed in a manner to supply the amino acids limiting growth. A problem with using this approach with cattle is that amino acids contained in feed protein do not represent those that will be available for tissue synthesis. Due to microbial fermentation in the rumen, a portion of the feed protein is degraded and converted to microbial protein. The undegraded protein is then available for post-ruminal digestion and supplements microbial protein as a source of metabolizable amino acids.

Substantial information has been provided on the amino acid composition and nutritive value of microbial protein. However, little information is currently available on the nutritive value of undegraded feed protein. A laboratory method was developed to measure the amino acid composition of undegraded feed protein by using ruminal microorganisms to release amino acids during ruminal fermentations. The protein sources investigated were soybean meal, casein, peanut meal, meat and bone meal, blood protein and five cottonseed meals. Data from this study indicates that the amino acid profile of feed protein changes after ruminal fermentation.

Certain amino acids were degraded to a greater extent than others with all of the protein sources tested. Of the essential amino acids studied, arginine, lysine, histidine and phenylalanine were degraded to the greatest extent. Therefore, the relative content of these important amino acids is less in undegraded feed protein than in the original feed protein. The primary significance of this work is to demonstrate that not only is there an absolute decrease in the amount of feed protein leaving the rumen, but that this undegraded feed protein also has a different amino acid profile. Further studies are needed to establish the bioavailability of these amino acids.

PR-3927

Central Nervous System (CNS) Control of Anterior Pituitary (AP) Hormone Secretion

L. A. Rund, M. S. Amoss, Jr., and P. G. Harms

There have been a variety of observations which indicate that the CNS has the ability to alter the secretions of the AP. However, few experiments have been performed in the bovine which provide information about how this is accomplished. Scientists in the Experiment Station have developed the technique of surgically placing a permanent cannula into the third ventricle of the brain. With this device we can administer drugs directly into the CNS. A series of experiments has been undertaken to determine the role of a class of drugs called neurotransmitters on the control of the secretion of luteinizing hormone (LH), follicle stimulating hormone (FSH), growth hormone (GH), thyroid stimulating hormone (TSH), prolactin (Prl), and adrenocorticotropin (ACTH) from the AP. These neurotransmitters are the chemicals by which the brain communicates with itself and with other parts of the body.

Heifers (both pre- and post-puberal) with a permanently implanted third ventricular cannula are fitted with an indwelling jugular vein catheter. Blood samples are taken at 15 minute intervals for 4 hours prior to the adminstration of the neurotransmitter and for 4 hours after the drug has been administered. Serum hormone levels are determined by radioimmunoassay techniques specific for each hormone.

To date serum LH values have been determined after administration of 100 micrograms each of norepinephrine, dopamine and serotonin. There is evidence that norepinephrine may decrease LH levels in the bovine which is the reverse of the response observed in rats. Serotonin has also produced a slight decrease in serum LH. To test this result completely, it will be necessary to peform this series of experiments in ovariectomized heifers in which the serum LH levels will be elevated. It is still of extreme importance to find a neurotransmitter which will elevate serum LH.

Understanding how the brain communicates with the endocrine system will enable scientists to devise a whole new series of synthetic drugs through which such phenomena as eating, reproduction, basal metabolic rate, growth and responses to stress may be controlled.

PR-3928

Time-on-Feed Effects on Tenderness Characteristics of Three Breed-Types of Cattle

F. K. McKeith, G. C. Smith, J. W. Savell, T. R. Dutson, and Z. L. Carpenter

A great deal of interest has been generated concerning cooked muscle tenderness differences among British, Brahman and Brahman-cross breed-types. Most research indicates that beef from Brahman cattle is less tender than that from the British breeds of cattle. Other research indicates that, directly or indirectly, time-on-feed is related to beef tenderness. The present study is being conducted to determine if such tenderness differences exist and, if so, to identify the chemical and histological factors that contribute to differences in the tenderness of the major muscles of carcasses from Angus, Brahman and Brahman × Angus breed-types fed a high-concentrate diet for 0, 56, 112, 168 or 224 days.

Steaks used, with the involved muscles listed parenthetically, were: top loin (longissimus), tenderloin (psoas major), top sirloin (biceps femoris and gluteus medius) and round (semimembranosus, biceps femoris and semitendinosus). With the excep-

tion of the psoas major, cooked muscles from Angus and Brahman × Angus steers had significantly lower ($P<.05$) shear force values than cooked muscles from Brahman steers. Shear force values for muscles from each breed-type at each time-on-feed indicated that steers of all three breed-types should be fed for 112 to 168 days to achieve "acceptable" tenderness (no more than 11 lb. of shear force) for most of the major muscles.

Exceptions to the 112 to 168 days requirement were: no feeding was necessary for the psoas major from all three breed-types or for the biceps femoris and semimembranosus from Angus and Brahman X Angus to produce "acceptable" beef and only 56 days of feeding was required to produce "acceptably" tender gluteus medius and semitendinosus from the Angus steers. Further chemical and histological studies — collagen concentration, collagen-solubility, muscle fiber diameter and sarcomere length — are being conducted in an effort to explain tenderness differences among breed-types and among feeding periods.

PR-3929

Analysis and Synthesis of Optimal Beef Cattle Production Systems

T. C. CARTWRIGHT, G. M. SMITH, C. R. SHUMWAY, D. E. FARRIS AND C. R. LONG

Resources for beef cattle production vary for each area of the state so that the system that produces most efficiently in one area may be different from the system that produces most efficiently in another area. Also, efficient utilization of a production resource depends on the relationship of cattle prices to production costs; these price-cost relationships change from time to time. Therefore, production decisions must be made in the context of the current and projected economic environment as well as physical environment or production area.

Designing production systems that are an optimal combination of breeding, feeding, management and marketing practices is a complex problem that is not directly addressed by any single scientific field. The proposed research will locate and organize research information from each separate field of genetics, nutrition, physiology, etc. relating to cattle production. This body of isolated facts will be combined in a form that will relate them in a scientific cause-and-effect manner to actual cattle production. A mathematical model that is computer programmed to simulate cattle herds within specific production areas has already been developed and tested for validity. The simulated output is in a useful form for biological and economic analysis of various production costs and market prices. The biological analysis will provide a basis for determining which alternative practices are feasible while the economic analysis will provide a basis for developing a strategy to combine the practices in a manner that will maximize return. After base analyses are established for an area, simulations and analyses can be performed on a timely basis in order to respond to economic or physical change such as cyclic or rapid changes in cattle markets, feed prices or droughts. For example, current market trends are clearly toward lean beef; systems analysis of both the biological and economic aspects of lean beef production is needed in order to synthesize efficient methods of producing lean beef, to determine how to efficiently shift production emphasis to lean beef, and to examine the impact such a shift would have on total beef supply, grain use, etc.

The research involves use of a general cattle simulation model (TAMU Beef Cattle Production Systems Model) that has been developed over the past 5 years and widely validated for structure and functions. This model simulates beef cattle herds, or components of herds, for specific types of cattle and production resources for which specific parameters are set in the model. The sequence of objective for this research are: (1) adapt the TAMU model for specific areas of Texas and for different production practices; (2) simulate beef cattle production systems to determine the effects of each of a number of different practices on net life-cycle productivity; (3) analyze the simulated results, component by component, in terms of biological efficiency and economic efficiency and viability; (4) synthesize production systems with optimal combinations of components that tend to maximize output/input (profit) for each location and market objective, such as weaned calves, stockers, feeders, and terminal lean beef steers/bulls; (5) adapt the general production strategy for use of current economic data in the day-to-day decision process; and (6) examine the effects of present and future beef production technologies, such as a major shift from producing choice steers to producing lean beef, on net productivity of individual beef herds and on an industry-wide basis.

An example of an application that has been made of this systems analysis approach is that of using data from the Texas A&M University Research and Extension Center at Overton. Cattle and forage data previously collected on crossbred cows, bermudagrass overseeded with legume and ryegrass pastures, and coastal bermudagrass hay were utilized. Simulations of this resource were validated by closely reproducing by simulation the recorded cattle production in all aspects of growth and reproduction. The "validation run" was then set as the "baseline run". Potential for increased productivity of this resource was then examined by simulation of a range of alternative practices and compared with the baseline. Economic analysis was applied and "profit risk frontiers" using 1972 to 1978 costs and prices were developed. The follow-

ing practices were among those simulated as optimal, or most profitable, for the Overton areas production resource:

Cow-calf operation (vs. stocker or pasture finishing).

Fall calving (vs. spring).

Common bermudagrass overseeded with clover-ryegrass plus coastal bermudagrass hay (vs. other pasture and hay combinations).

Critical winter hay feeding at about 80 percent of the amount a dry cow would consume (vs. higher and lower levels). Compared to lower levels, hay feeding at this 80 percent level decreased number of cows/unit land, increased production/cow and increased farm profit.

PR-3930

Observations on Receiving New Cattle

D. P. HUTCHESON

When cattle are subjected to stresses during market and transit, many metabolic changes occur. These changes are depicted as a voluntary reduction of feed intake during the first week at a feedyard. During this time, calves consume feed at the rate of .5 to 1.5 percent of their body weight. During the next week, they consume feed at the rate of 1.5 to 2.5 percent of their body weight. Sometime after the 14th day and usually by the 28th day, they consume 2.5 to 3.5 percent of their body weight.

The abnormally low feed intake during the first several weeks creates problems in ration formulation. When the calf is only consuming 1 percent of its body weight, it is virtually impossible to formulate a ration for the calf to gain weight. The concentration of energy necessary for the calf to gain .5 pound per day is 128 mcal of net energy for maintenance per 100 pounds of feed and 61 mcal of net energy for gain per 100 pounds of feed. Corn has about 104 mcal of net energy for maintenance per 100 pounds; therefore, corn, by itself, would not support gains at this intake. However, if the calf is consuming 2 percent of its body weight, then a diet containing about 13 percent protein, 76 mcal of net energy for maintenance per 100 pounds, and 46 mcal of net energy for gain will support approximately 1 pound per day of gain. This diet is approximately a 70 percent concentrate diet.

An electronic feed monitoring device, referred to as pinpointers, was used at our experimental feedlot during the past year to monitor individual feed intake of calves. Feed intakes of calves eating from the pinpointers and calves fed in small herds, have been found to be similar. The average feed intake after 28 days was 13.2 pounds for pinpointer calves and 12.7 pounds for calves fed in small herds. The average percentage of calves eating from either system the first day after arrival was 22 percent. Knowledge of feed intake patterns should be carefully considered in ration formulation to maintain the desired performance of newly delivered calves.

PR-3931

Cattle Blood Typing

D. F. WESELI AND J. CALDWELL

The Texas A&M Immunogenetics Laboratory has responsibility for contract blood typing for the majority of the cattle registry associations in the U.S. During the past year 16,046 samples were typed for 58 different factors, genetically interpreted and a parentage determination performed when possible. A breakdown, by breed, of the number of individuals blood-typed is listed below:

Holstein	11,460	Guernsey	244
Hereford	817	Brangus	215
Jersey	545	Ayrshire	142
Charolais	486	Longhorn	88
Brahman	380	Santa Gertrudis	63
Beefmaster	342	White Park	38
Gelbvieh	328	Marchigiana	28
Brown Swiss	307	Milking Shorthorn	27

The remainder of the samples were from a number of other breeds and experimental samples for research. The breed reigstry associations utilize blood typing information in a number of programs. All bulls used in artificial breeding are required to be typed so the information is available in case of parentage questions in the future. Many breed organizations have a random sampling program to check the accuracy of registration of sire and dam. Blood typing is also used to solve such problems as cross-switched calves, multiple sire breeding, calving beyond the normal gestation length and freemartin determination. The increased popularity of embryo transfer has opened another area for use of parentage verification or determination by use of blood typing, especially when mixed semen is used.

During the past year a major effort was undertaken to characterize the genetic blood groups in the Brahman breed. This was made possible by the accumulation of sufficient family data over the past 8 years. Approximately 60 new groups in the B system were isolated; these groups are not known to occur in any of the European breeds of cattle. A number of new blood groups were also discovered in the Texas Longhorn and American breeds.

The data base in the TAMU Immunogenetics Laboratory files now includes records on more than 80,000 individual cattle. A computerized record keep-

ing system for the complex blood type data has been developed. This computer system provides instant access to any individual record and is programmed to automatically perform genetic interpretations of the base laboratory data in most cases. Also, the computerized data are in convenient form for analysis of breed structure and other research uses.

PR-3932

Estimation of Whole Body Protein Turnover in Growing Steers

K. E. Lanka and G. A. Broderick

Summary

Experiments were conducted to determine (a) body protein synthesis and breakdown (b) body protein, water and weight, excluding the digestive tract and (c) rates of irreversible loss of amino acids and water from the bodies of growing Angus steers. Two methods were compared for measuring protein synthesis and breakdown (turnover). A nitrogen balance study, during which a muscle protein metabolite, 3-methylhistidine, was measured in the urine, provided estimates of whole body protein synthesis and breakdown. In this study, protein breakdown and net protein synthesis were .39 lb/day and .27 lb/day, respectively. Total protein synthesis was .66 lb/day, and turnover rate of total body protein was .73 percent/day. In a second study, radioactively labeled amino acids (lysine and threonine) were infused into the jugular veins of the steers to determine body protein synthesis and irreversible loss of the amino acids. Deuterium oxide (heavy water) was injected into the bloodstream to determine body protein, water and weight, excluding the digestive tract contents. From this study, body protein synthesis was determined to be .78 lb/day, and empty body protein, water, and weight were determined to be 110.2 lb, 365.0 lb and 697.4 lb, respectively. Average daily loss of amino acids catabolized for energy was 3.58 g of lysine and .56 g of threonine. Turnover rate of total body protein was estimated to be .71 percent/day, by the labeled amino acid and deuterium oxide method.

Introduction

Of all tissues in the bodies of animals, skeletal muscle is the largest (5). Since proteins comprise a major proportion of muscle cells, these large molecules play an important and significant role in total body metabolism. Proteins are dynamic molecules which are constantly changing. Some proteins are metabolized rapidly, and their periods of utility are short. Others, e.g., collagen, have long life spans, and they are slow to change. Regardless of the speed or rate of alteration, all do change. The process of anabolism and subsequent catabolism is known as "turnover"; and body proteins in animals, both young and old, are in continuous renewal and replacement. Until the introduction of tracer atoms into the field of nutrition and metabolism, it was impossible to assess the magnitude of the synthesis and degradation involved in the turnover of proteins. The process of protein turnover has been studied in several species of animals, but until recently, there have been no studies which concerned turnover in cattle. By knowing the specific rates of turnover, a useful estimate can be made of energy and amino acid requirements necessary to meet the demands for protein replacement.

Experimental Procedure

Four growing Angus steers were used in a nitrogen balance study to determine net protein retention. Total body protein breakdown was estimated by analysis of 3-methylhistidine in the urine, and total body protein synthesis was determined by summation of net protein synthesis and breakdown. Diets of the animals consisted of ground grain sorghum, alfalfa leaf meal, and cottonseed hulls, supplemented with calcium, phosphorus, salt and vitamin A (4). The diet contained 11.3 percent crude protein on an as-fed basis.

Two of the steers from the nitrogen balance study were used for the isotopically labeled amino acid studies. The amino acids in solution were infused through jugular catheters from a constant infusion pump. Immediately prior to the infusion, each steer was injected (via catheter) with 75 cc of deuterium oxide. Blood samplels were collected periodically for later radioactivity, amino acid and deuterium oxide analyses.

Results and Discussion

Net protein synthesis was determined by multiplying nitrogen retention by 6.25. Protein breakdown was determined by analysis of 3-methylhistidine, a muscle protein amino acid. The amino acid is neither metabolized nor re-utilized by cattle, and it is excreted rapidly through the urine (3). The concentration of 3-methylhistidine in mixed muscle protein has been found to be 594 parts per million (6). Protein in lean and fat has been found to comprise 53 percent of total body protein for steers of similar size to those used for these experiments (1). Protein in lean and fat was considered in this experiment as being the same as muscle. Division of total daily excretion of 3-methylhistidine by the concentration of it in muscle protein yielded the weight of muscle protein degraded daily. It was assumed that muscle proteins degraded at the same rate as other body proteins, and since muscle protein is 53 percent of total body protein, total body protein breakdown was calculated.

TABLE 1. NITROGEN RETENTION, NET PROTEIN SYNTHESIS, 3-METHYLHISTIDINE EXCRETION, PROTEIN DEGRADATION AND TOTAL PROTEIN SYNTHESIS IN STEERS

Steer identification	weight	Nitrogen retention	Net protein synthesis	3-Methylhistidine excretion	Protein degradation		Total protein synthesis
					muscle	whole body	
	(lb)	(lb/day)	(lb/day)	(mg/day)	(lb/day)	(lb/day)	(lb/day)
555	587	.022	.14	43.6	.16	.30	.44
699	660	.038	.23	69.8	.26	.49	.72
707	658	.063	.39	33.2	.13	.25	.64
754	609	.051	.32	75.6	.28	.53	.85
Average	628	.044	.27	55.5	.21	.39	.66

TABLE 2. DAILY PROTEIN SYNTHESIS IN ISOTOPIC INFUSION STUDIES AND IRREVERSIBLE LOSSES OF AMINO ACIDS FOR ENERGY

Period of Study	Steer identification	Amino acid infused	Protein turnover rate	Irreversible loss of infused amino acid	
			(lb/day)	(%/day)	(g/day)
1	699	lysine	.99	8.6	3.01
1	707	threonine	.21	7.4	.31
2	707	lysine	1.44	8.2	4.15
2	699	threonine	.46	8.9	.80
Average		lysine	1.22	8.4	3.58
Average		threonine	.34	8.2	.56

Results of this experiment are shown in table 1. Average net protein synthesis was .27 lb/day, and can be considered to represent protein growth. Total body protein degradation was calculated to be .39 lb/day. Total protein synthesis was thus .66 lb/day. Protein growth accounted for only 41 percent of total protein synthesis, due to replacement of degraded proteins. This replacement is energetically costly to the animal, and a reduction in protein breakdown would result in a reduced maintenance requirement.

Results of protein turnover rates from the radioisotopic infusion experiment are shown in table 2. Calculations of protein turnover were variable between steers infused with lysine and threonine, however the average total body protein turnover rate was .78 lb/day. Irreversible losses of lysine and threonine through metabolism for energy were 8.4 percent/day and 8.2 percent/day, respectively.

Body protein, water and weight, excluding the digestive tract, were calculated from concentration of deuterium oxide in blood water (2). These results are shown in table 3. Noting that the average protein content of the whole bodies was 14.3 percent, it could be estimated by nitrogen balance techniques that total protein turnover was (.66/90) × 100, or .73 percent/day. From radioisotopic techniques, protein turnover rate was estimated to be (.78/110) × 100, or .71 percent/day. These results provide useful information concerning the amounts of protein synthesized and broken down daily by a growing steer. Perhaps more importantly, they provide the basis for determination of energy costs to the animal in terms of maintenance and production associated with protein metabolism. Based on the results of this study, it was estimated that protein turnover accounted for 5.1 percent of net energy costs for maintenance for 700 lb steers.

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TABLE 3. EMPTY BODY PROTEIN, WATER AND WEIGHT FROM DEUTERIUM OXIDE ANALYSIS AND LIVE WEIGHT IN STEERS

Period of Study	Steer identification	Empty body protein	Empty body water	Empty body weight	Live weight
		(lb)	(lb)	(lb)	(lb)
1	707	113.7	376.8	690.9	776.6
1	699	101.6	336.7	651.0	752.4
2	707	108.9	360.8	728.9	767.8
2	699	116.4	385.7	718.8	787.6
Average	overall	110.2	365.0	697.4	771.1

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PR-3933

Influence of Subcutaneous Fat Thickness, Marbling and Electrical Stimulation on the Palatability of Beef From Young Bulls

R. R. Riley, J. W. Savell, C. E. Murphey, G. C. Smith, D. M. Stiffler and H. R. Cross

Summary

Ninety-five grain-finished young bulls were slaughtered and the right side of each carcass was electrically stimulated (ES) while the left side was not stimulated (not-ES). One side of each of 29 not-ES U.S. Choice steer carcasses and one side of each of 72 not-ES U.S. Good or U.S. Standard steer carcasses were also selected. Each of the ES and not-ES bull sides with less than a Small amount of marbling and each of the U.S. Good and Standard steer sides was allotted to one of two groups — (1) U.S. Good with at least .30 inch fat thickness and (2) U.S. Standard and U.S. Good with less than .30 inch fat thickness.

ES had essentially no effect on the palatability of steaks from U.S. Good bulls with at least .30 inch fat thickness; however, ES significantly improved muscle fiber tenderness, overall tenderness, and overall palatability of steaks from U.S. Standard bulls and U.S. Good bulls that had less than .30 inch fat thickness. Steaks from U.S. Good steers or bulls that had at least .30 inch fat thickness did not differ from steaks from U.S. Choice steers in juiciness, overall tenderness, flavor, overall palatability or shear force values.

Steaks from U.S. Good bulls and steers that had less than .30 inch fat thickness and U.S. Standard bulls and steers were less palatable than steaks from U.S. Choice steers or U.S. Good bulls and steers that had at least .30 inch fat thickness. The data indicate that the USDA might well give further consideration to a revision of its beef grade standards which would permit "A" maturity carcasses with a "Slight amount" of marbling and at least .30 inch fat thickness to grade Choice.

Introduction

There is growing consumer demand for lean beef and, in order to meet this demand, there has been increased interest in modifying the USDA beef grade standards so that "A" maturity carcasses with a "Slight amount" of marbling would be eligible for the Choice grade provided they have (a) at least .30 inch fat thickness opposite the ribeye muscle at the 12th rib and (b) external fat that is not more than slightly yellow in color (3). Furthermore, to meet this demand for lean meat, there has been increased interest in the production of meat for the block-beef trade from young bulls; however, the production of young bulls for this purpose has been hindered by the requirement that if carcasses of young bulls are officially graded by the USDA, the word "Bullock" must be used in conjunction with the grade name (2). If the USDA beef grade standards were modified to reduce the marbling requirement for Choice and if "Bullock" was not required as a part of the USDA grade designation, beef production from young bulls might be increased.

This study compared the palatability of steaks from (1) U.S. Choice steer carcasses, (2) steer carcasses segmented into groups which had or had less than Slight marbling and which had at least or had less than .30 inch fat thickness, and (3) young bull carcasses segmented into groups which had or had not been electrically stimulated, which had or had less than Slight marbling and which had at least or had less than .30 inch fat thickness.

Experimental Procedure

A total of 95 grain-finished young bulls of various breeds obtained from the Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, NE were slaughtered at a commercial packing plant. Immediately upon entering the blast chill cooler (40-70 min postmortem), the right side of each carcass was electrically stimulated (ES) while the left sides were not stimulated (not-ES). Each ES side received 15 impulses of 550 volts, 2-2.5 amps and 1.8 sec duration with 1.8 sec between impulses. The source of electrical stimulation was an experimental "Lectro-Tender™" unit (LeFiell Company, San Francisco, CA).

Carcass evaluation and selection

At approximately 24 hr postmortem, Texas Agricultural Experiment Station (TAES) personnel evaluated (1) each bull carcass for USDA yield grade factors and skeletal maturity and (2) each bull side for USDA quality grade factors. Also, one side of each of 29 U.S. Choice steer carcasses and one side of each of 72 U.S. Good or U.S. Standard steer carcasses of unknown history were selected from the same packing plant. Each of these steer sides was further evalu-

ated for the same factors as the bull carcasses. Each of the ES and not-ES bull sides with less than a Small amount of marbling and each of the steer sides were allotted to one of two marbling/fat thickness groups as shown in Table 1.

Fabrication, packaging and storage

On the second day postmortem, each side was fabricated and the short-cut boneless strip loin was vacuum packaged, boxed, and stored at 34 F for 11 days and then transported to the TAES Meat Laboratory. On the fourteenth day after slaughter, two steaks (1.5 inch thick) were removed from each strip loin; the first steak was used for shear force determination and the second steak was used for sensory panel evaluation. Each steak was wrapped and frozen at −30 F and stored at −10 F.

Palatability traits and shear force

Each steak was removed from the freezer, thawed and broiled to an internal temperature of 158 F. Steaks for sensory panel evaluation were served, while warm, to a trained, eight-member sensory panel. Steaks for shear force determinations were cooled to room temperature (73 F) and one-half inch diameter cores were removed and sheared by the Warner-Bratzler shear machine.

TABLE 1. EXPERIMENTAL DESIGN

Group	Grade	N	Treatment[a]	Fat thickness greater than .30 inch[b]
A	U.S. Choice steers	29	Not-ES	Yes
B	U.S. Good steers	18	Not-ES	Yes
C	U.S. Good bulls	22	ES	Yes
D	U.S. Good bulls	22	Not-ES	Yes
E	U.S. Good and Standard steers	54	Not-ES	No
F	U.S. Good and Standard bulls	65	ES	No
G	U.S. Good and Standard bulls	67	Not-ES	No

[a]ES = electrically stimulated; not-ES = not electrically stimulated.

[b]Yes = sides with at least .30 inch adjusted subcutaneous fat thickness; No = U.S. Good sides with less than .30 inch adjusted subcutaneous fat thickness and all U.S. Standard sides (irrespective of fat thickness)

Results and Discussion

Comparisons of mean values for certain carcass traits among the U.S. Choice steer carcasses, the U.S. Good steer carcasses and the ES and not-ES young bull carcasses with at least .30 inch fat thickness are presented in Table 2. By design, the Choice steers had significantly higher marbling scores and USDA quality grades than the Good steers and each group of young bulls. Also, each group of young bull carcasses had significantly less fat over the 12th rib, larger ribeye muscle areas and lower numerical yield grades than either the Choice or Good steers. Furthermore, each group of young bulls had less kidney, pelvic and heart fat than the Choice steers and had heavier carcass weights than the Good steers. The Good steers had significantly less fat and lower numerical yield grades than did the Choice steers. The Choice steers and ES young bulls had significantly more youthful USDA lean maturity scores than did the Good steers. Although the ES bulls had more youthful appearing lean than the not-ES bulls, the difference was not significant. There were no significant differences among any of the four groups in skeletal maturity or overall maturity.

Palatability studies involving beef from young bull and steer carcasses have produced conflicting results. Research (5) has indicated that steaks from steers were significantly more tender than steaks from young bull carcasses while in other research (1) there were no significant differences in tenderness, juiciness or flavor ratings between steaks from young bull and steer carcasses. It has also been suggested that bull carcasses with a similar development of quality-indicating characteristics as steer carcasses could not be merchandised with confidence that the young bull beef would be equally as palatable as the steer beef (5). However, in the present study, there were very few (only 2 of 42 possible differences were statistically significant) differences in palatability among the four groups (Table 3). This agrees with previous studies reported by the National Cattlemen's Association (3) which found little or no difference in palatability when beef with a Slight amount of marbling and at least .30 inch fat thickness opposite the ribeye muscle was compared to beef in the present Choice grade.

Table 4 includes comparisons of mean values for certain carcass traits among U.S. Choice steer carcasses and U.S. Good and/or U.S. Standard steer and young bull carcasses differing in fat thickness. ES and not-ES young bulls in Groups F and G were significantly trimmer, had larger ribeye muscle areas and lower numerical yield grades than steers or young bulls in Groups A, B, C, D and E; less kidney, pelvic and heart fat than steers or bulls in Groups A, C and D and heavier carcass weights than steers in Groups A, B and E. Young bulls or steers in Groups E, F and G had significantly less marbling and lower USDA quality grades than bulls or steers in Groups A, B, C and D. Choice steers and ES young bulls in Groups C and F had more youthful USDA lean maturity than steers in Group B. No significant differences were found among any of the groups for USDA skeletal or overall maturity.

Comparisons of sensory panel ratings and Warner-Bratzler shear force values among steaks from U.S. Choice steers and steaks from U.S. Good and/or Standard steers and young bulls differing in fat thickness are presented in Table 5. Steaks from Choice steers (Group A) were juicier, had higher muscle fiber tenderness and overall tenderness scores and were more desirable in flavor and overall palatability than steaks from steers or young bulls in Groups E, F and G. Furthermore, steaks from Choice steers (Group A)

TABLE 2. COMPARISONS OF MEAN VALUES FOR CERTAIN CARCASS TRAITS AMONG U.S. CHOICE STEERS CARCASSES AND U.S. GOOD STEER AND YOUNG BULL CARCASSES WITH AT LEAST .30 INCH FAT THICKNESS

	U.S. Choice steers (n=29)	U.S. Good steers≥.30 in. fat thickness (n=18)	U.S. Good bulls≥.30 in. fat thickness	
			ES (n=22)	Not-ES (n=22)
Trait[d]	Group A	Group B	Group C	Group D
Adjusted fat thickness 12th rib, in.	.63[c]	.47[b]	.37[a]	.38[a]
Ribeye muscle area, in.[2]	12.8[b]	13.4[b]	14.7[a]	14.6[a]
Kidney, pelvic, and heart fat, %	2.1[b]	1.8[a]	1.9[a]	1.9[a]
Carcass weight, lb	750[bc]	710[c]	799[a]	792[ab]
USDA skeletal maturity	A[55][a]	A[56][a]	A[64][a]	A[62][a]
USDA lean maturity	A[59][a]	A[76][b]	A[56][a]	A[70][ab]
USDA overall maturity	A[57][a]	A[56][a]	A[60][a]	A[61][a]
USDA marbling	Sm[65][a]	Sl[34][b]	Sl[41][b]	Sl[45][b]
USDA quality grade	Ch[22][a]	G[32][b]	G[41][b]	G[45][b]
USDA yield grade	3.2[c]	2.5[b]	2.1[a]	2.1[a]

[a,b,c]Means in the same row bearing a common superscript letter are not different (P>.05).

[d]All carcasses were quality and yield graded according to USDA (7) grade standards.

TABLE 3. COMPARISONS OF PALATABILITY CHARACTERISTICS AMONG TOP LOIN STEAKS FROM U.S. CHOICE STEERS AND FROM U.S. GOOD STEERS AND YOUNG BULLS WITH AT LEAST .30 INCH FAT THICKNESS

	U.S. Choice steers (n=29)	U.S. Good steers≥.30 in. fat thickness (n=18)	U.S. Good bulls≥.30 in. fat thickness	
			ES (n=22)	Not-ES (n=22)
Characteristic	Group A	Group B	Group C	Group D
Juiciness[c]	5.6[a]	5.2[a]	5.3[a]	5.6[a]
Muscle fiber tenderness[c]	6.5[a]	6.4[ab]	6.0[b]	6.1[ab]
Connective tissue amount[d]	7.6[ab]	7.7[a]	7.6[a]	7.4[b]
Overall tenderness[c]	6.6[a]	6.4[a]	6.1[a]	6.2[a]
Flavor[c]	6.0[a]	5.8[a]	5.7[a]	5.8[a]
Overall palatability[c]	6.1[a]	5.9[a]	5.7[a]	5.9[a]
Warner-Bratzler shear force (lb)	6.0[a]	6.5[a]	6.6[a]	6.5[a]

[a,b]Means in the same row with a common superscript are not different (P>.05).

[c]Means based on eight-point descriptive scales (8=extremely juicy, extremely tender or extremely desirable; 1=extremely dry, extremely tough or extremely undesirable).

[d]Means based on eight-point rating scale (8=none; 1=abundant).

had significantly less connective tissue and lower shear force values than steaks from young bulls in Groups F and G. Steaks from young bulls or steers in Groups B, C and D had lower shear force values and higher or equal palatability ratings in 59 of 63 comparisons (28 were statistically significant) than steaks from young bulls or steers in Groups E, F and G.

The use of ES is well-documented as a means of increasing beef tenderness and improving its overall palatability (4,6). In the present study, ES had a greater effect on the palatability of steaks from U.S. Good and Standard young bulls with less than .30 inch fat thickness than it did on steaks from U.S. Good young bulls with at least .30 inch fat thickness. ES of young bulls resulted in steaks from Group F having significantly higher muscle fiber tenderness, overall tenderness and overall palatability ratings than steaks from the not-ES young bulls in Group G. These data suggest that subcutaneous fat thickness of .30 inch or more may minimize the beneficial effects of ES on beef palatability.

In conclusion, these data suggest that ES had a greater effect on improving the palatability of steaks from U.S. Good young bull carcasses with less than .30 inch fat thickness and U.S. Standard bull carcasses than it had on the palatability of steaks from U.S. Good young bull carcasses with at least .30 inch fat thickness. The data also reveal that U.S. Good steer

TABLE 4. COMPARISONS OF MEAN VALUES FOR CERTAIN CARCASS TRAITS AMONG U.S. CHOICE STEER CARCASSES AND U.S. GOOD AND STANDARD STEER AND YOUNG BULL CARCASSES DIFFERING IN FAT THICKNESS

		U.S. Good≥.30 in. fat thickness			U.S. Good <.30 in. in fat thickness and U.S. Standard		
	U.S. Choice		Young bulls			Young bulls	
	steers (n=29)	Steers (n=18)	ES (n=22)	Not-ES (n=22)	Steers (n=54)	ES (n=65)	Not-ES (n=67)
Trait[e]	Group A	Group B	Group C	Group D	Group E	Group F	Group G
Adjusted fat thickness 12th rib, in.	.63[d]	.47[c]	.37[b]	.38[b]	.33[b]	.20[a]	.19[a]
Ribeye muscle area, in^2	12.8[c]	13.4[c]	14.7[b]	14.6[b]	13.2[c]	15.7[a]	15.6[a]
Kidney, pelvic, and heart fat, %	2.1[c]	1.8[abc]	1.9[bc]	1.9[bc]	1.7[ab]	1.6[a]	1.6[a]
Carcass weight, lb	750[bc]	710[cd]	799[ab]	792[ab]	706[d]	801[a]	801[a]
USDA skeletal maturity	A[55a]	A[56a]	A[64a]	A[62a]	A[56a]	A[61a]	A[61a]
USDA lean maturity	A[59a]	A[76b]	A[56a]	A[70ab]	A[68ab]	A[62a]	A[70ab]
USDA overall maturity	A[57a]	A[66a]	A[60a]	A[61a]	A[62a]	A[60a]	A[64a]
USDA marbling	Sm[65a]	Sl[34b]	Sl[41b]	Sl[45b]	Tr[60c]	Tr[49c]	Tr[49c]
USDA quality grade	Ch[22a]	G[32b]	G[41b]	G[45b]	St[82c]	St[77c]	St[77c]
USDA yield grade	3.2[d]	2.5[c]	2.1[b]	2.1[b]	2.1[b]	1.3[a]	1.4[a]

[a,b,c,d]Means in the same row with a common superscript letter are not different (P>.05).

[e]All carcasses were quality and yield graded according to USDA (7) grade standards.

TABLE 5. COMPARISONS OF PALATABILITY CHARACTERISTICS AMONG TOP LOIN STEAKS FROM U.S. CHOICE STEERS AND FROM U.S. GOOD AND STANDARD STEERS AND YOUNG BULLS DIFFERING IN FAT THICKNESS

		U.S. Good≥.30 in. fat thickness			U.S. Good <.30 in. fat thickness and U.S. Standard		
	U.S. Choice		Young bulls			Young bulls	
	steers (n=29)	Steers (n=18)	ES (n=22)	Not-ES (n=22)	Steers (n=54)	ES (n=65)	Not-ES (n=67)
Characteristic	Group A	Group B	Group C	Group D	Group E	Group F	Group G
Juiciness[e]	5.6[a]	5.2[b]	5.3[ab]	5.6[a]	5.2[b]	5.2[b]	5.1[b]
Muscle fiber tenderness[e]	6.5[a]	6.4[ab]	6.0[abc]	6.1[abc]	6.0[bc]	5.7[c]	5.3[d]
Connective tissue amount[f]	7.6[a]	7.7[a]	7.6[a]	7.4[ab]	7.6[a]	7.3[b]	7.3[b]
Overall tenderness[e]	6.6[a]	6.4[ab]	6.1[abc]	6.2[abc]	6.0[bc]	5.7[c]	5.3[d]
Flavor[e]	6.0[a]	5.8[ab]	5.7[abc]	5.8[a]	5.5[c]	5.5[bc]	5.5[c]
Overall palatability[e]	6.1[a]	5.9[ab]	5.7[abc]	5.9[ab]	5.5[bc]	5.3[c]	5.0[d]
Warner-Bratzler shear force (lb)	6.0[a]	6.5[ab]	6.6[ab]	6.5[ab]	6.4[a]	7.0[bc]	7.3[c]

[a,b,c,d]Means in the same row with a common superscript letter are not different (P>.05).

[e]Means based on eight-point descriptive scales (8=extremely juicy, extremely tender or extremely desirable; 1=extremely dry, extremely tough or extremely undesirable).

[f]Means based on eight-point rating scale (8=none; 1=abundant).

and/or young bull carcasses with at least .30 inch fat thickness produced steaks that were comparable in palatability to steaks from U.S. Choice steer carcasses. Therefore, it would appear that further consideration might well be given to a revision of the USDA beef grade standards which would permit all "A" maturity carcasses (from steers, heifers or young bulls) with a Slight amount of marbling and at least .30 inch fat thickness to grade Choice. These data would also support eliminating the requirement that the word "Bullock" be included in the grade identification for carcasses from young bulls. If such changes were made, they might cause a dramatic increase in production of young bulls for the block beef trade. On the other hand, the data indicate that beef from Standard Bullock carcasses and from Good Bullock carcasses with less than .30 inch fat thickness was inferior in palatability to steer beef with similar characteristics. These data support the USDA requirement that when beef from young bulls is graded it also be identified as "Bullock" as a means to distinguish it from beef of the same grade from other sexes. These conflicting results indicate that additional research is needed to determine the effects of sex condition on beef palatability.

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PR-3934

Retail Appearance and Palatability Characteristics of Commercially Transported-Distributed, Electrically Stimulated, U.S. Choice Beef

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Summary

The left sides of U.S. Choice carcasses were electrically stimulated (ES) and the right sides were not (Not-ES); sides were transported to a retail distribution center, fabricated and packaged. Vacuum packaged subprimal cuts (top round, bottom round, loin, ribeye, blade chuck, English cut) were shipped to a retail store and fabricated into retail cuts. Weight loss of vacuum packaged primals during storage did not differ ($P>.05$) between ES and Not-ES treatments for any of the six subprimal cuts. Muscle color of seven-bone roasts at the beginning of retail display was the only appearance characteristic improved ($P<.05$) for any steak or roast as a result of ES. No significant differences ($P>.05$) were observed between ES and Not-ES beef for muscle color, surface discoloration or overall appearance of top round or porterhouse steaks. ES did not significantly ($P>.05$) affect the shrink loss of retail cuts at 2 or 3 days of display. Microbiological evaluations of ES and Not-ES retail cuts did not produce consistent results. Muscle fiber tenderness for sirloin steaks increased ($P<.05$) as a result of ES; however, ES resulted in higher ($P<.02$) shear force values for ribeye steaks. Neither sensory panel ratings nor shear force values differed ($P>.05$) between treatments for bottom round roasts; however, English cut roasts from ES sides had lower sensory panel ratings for amount of connective tissue ($P<.03$), overall tenderness ($P<.008$) and overall palatability ($P<.04$) than did English cut roasts from Not-ES sides.

Introduction

Electrical stimulation (ES) has been demonstrated (10,13) to result in advantages for packers (brighter colored lean, improved setting-up of marbling, reduced incidence of "heat-ring" and earlier time of ribbing); retailers (improved retail appearance and tenderness assurance); purveyors (reduced aging time); restaurateurs (improved tenderness without "over-tenderizing") and consumers (improved palatability). However, a shortcoming of previous studies is that they have not been conducted in a manner that facilitated following ES and Not-ES beef through the typical transportation-distribution cycle. Therefore, the present study was conducted to investigate the effect of ES on the weight loss of vacuum packaged beef subprimal cuts, the appearance of retail cuts and the palatability of steaks and roasts from U.S. Choice beef that was followed from slaughter to retail to ultimate consumption using a transportation-distribution sequence characteristic of that presently used in the beef industry.

Experimental

Basic design

Seventy-nine cattle slaughtered at a commercial packing plant served as the base population for this study. The left side of each carcass was electrically stimulated (ES) immediately upon entering the cooler (1-1.5 hr postmortem) and the right side served as an untreated (Not-ES) control. This study was conducted in cooperation with a major national retail grocery company; their personnel and facilities were used extensively in all phases of the study.

Electrical stimulation

Electrical stimulation was applied by an experimental "Lectro-Tender™" unit manufactured by LeFiell Co., San Francisco, California. Each ES side received 15 impulses of 550 volts (AC), 2-2.5 amps of 1.8 sec duration each, with 1.8 sec between impulses.

Carcass selection and evaluation

After 22 hr of chill, sides were ribbed and presented for grading. Twenty U.S. Choice carcasses with yield grades of 2 or 3, and with carcass weights of 600 to 850 lb were randomly selected for further study. Measurements or scores for factors used in yield and quality grading of beef were obtained by Texas Agricultural Experiment Station (TAES) personnel for each carcass. At approximately 26 hr postmortem, carcasses were transported to a retail distribution center.

Fabrication, packaging, and storage

Upon arrival at the distribution center, carcasses were chilled (34 ± 2 F) for an additional 20 hr. Carcasses were fabricated by retail distribution center per-

sonnel and the following subprimal cuts were removed from each side: top round, bottom round, saw-ready loin, ribeye, saw-ready blade chuck and boneless English cut. Subprimal cuts were vacuum packaged, weighed, boxed and stored at the retail distribution center for 13 days before being shipped to a retail store.

Subprimal weight loss

At the retail store, the packaging material was removed from each subprimal cut, the cut was weighed and steaks and roasts were cut. Since the original weight for each subprimal cut was obtained after vacuum packaging, packaging material from each subprimal cut was dried and weighed after its removal. Weight loss of the vacuum packaged subprimals was calculated as a percentage of the original subprimal cut weight minus the weight of the packaging material.

Subprimal fabrication

All steaks and roasts for retail display and palatability evaluations were cut by the retail store personnel. Steaks were cut approximately 1.0 in. thick and roasts were cut approximately 2.0 in. thick. All cutting and trimming was done under normal retail store conditions. For palatability evaluations, ribeye steaks, sirloin steaks, bottom round roasts and English roasts were removed from each respective subprimal cut at 16 days postmortem. These steaks and roasts were wrapped, frozen at −30 F and stored at −10 F. For retail display evaluations, porterhouse steaks, top round steaks and seven-bone roasts were cut from each respective subprimal cut at 17 days postmortem. These steaks and roasts were individually placed on plastic foam trays and the package was overwrapped with polyvinyl chloride film.

Retail display

After packaging, steaks and roasts designated for retail display were transported 3 mi to the TAES laboratory and displayed in retail display cases at 34-37 F under 150 footcandles of fluorescent light following commercial time-patterns of lighting (15 hr on, 9 hr off). At 24-hr intervals, a ten-member trained panel evaluated the retail cuts for muscle color (15 = bright cherry red, 1 = extremely dark brown), surface discoloration (15 = no surface discoloration, 1 = total surface discoloration) and overall appearance (15 = extremely desirable, 1 = extremely undesirable). Steaks were displayed for 3 days and roasts were displayed for 2 days. Retail cuts were weighed at the beginning and end of retail display in order to determine shrinkage loss.

Microbiological evaluation

Samples for bacterial counts were taken from three randomly chosen pairs (ES and Not-ES) of retail cuts. Roasts were sampled at the beginning and end of retail display and steaks were sampled at the beginning, during, and at the end of retail display. Retail cuts were sampled by removing a 10 cm^2 (2mm thick) area from the top of the retail cut with a sterile scalpel. These samples were placed in 100 ml of sterile 0.1 percent peptone and macerated in a Stomacher-400 for 1 min. Aerobic plate counts were determined by plating 0.1 ml volumes of appropriate dilutions on pre-poured plates of tryptic soy agar (TSA, Difco). Plates were incubated for 3 days at 77 F. Aerobic plate counts were calculated from countable plates and expressed per cm^2.

Palatability determinations

Each steak or roast was removed from the freezer, thawed (36 F) and cooked to an internal temperature of 158 F for sensory panel and Warner-Bratzler shear force determinations. Cooking procedures were as follows: ribeye and sirloin steaks were broiled; bottom round roasts were roasted in a 350 F gas oven; and English cut roasts were placed on racks in an electric skillet with 8 oz. of water, covered and moist-heat cooked at 225 F. After cooking, steaks and roasts were cut into halves and one half was served, while warm, to a trained eight-member sensory panel. The other half was cooled to room temperature (73 F), 0.5 in. in diameter cores were removed and shear force determinations were obtained with a Warner-Bratzler shear machine.

Results and Discussion

In order to adequately describe the carcasses used in this study, certain traits were obtained for each carcass. Means with standard deviations in parentheses for USDA yield and quality grade factors were as follows: hot carcass weight, lb. = 748.2 (54.5); adjusted fat thickness, 12th rib, in. = .61 (0.2); kidney, pelvic, and heart fat, % = 2.63 (0.7); ribeye muscle area, sq. in. = 13.1 (1.0); marbling = Modest^{03} (67.9); USDA quality grade = Choice^{34} (22.7); and USDA yield grade = 3.2 (0.5).

Comparisons of vacuum packaged subprimal cuts from electrically stimulated (ES) and untreated (Not-ES) sides (data not presented in tabular form) revealed that weight loss during storage did not differ ($P>.05$) between treatments for any of six subprimal cuts. The beef industry has expressed concern regarding possible increase in shrink or "weepage" loss of vacuum packaged subprimals which might occur due to the use of ES in the beef slaughtering operation. Data from the present study suggest that such concern is unwarranted; subprimal cuts from ES beef sides did not sustain greater weight losses than did cuts from Not-ES beef sides. This agrees with previous findings (7) which determined that ES did not substantially affect the weight loss of vacuum packaged lamb cuts.

Research involving retail appearance evaluations of lamb chops (7,8), beef steaks (3) and calf steaks (9) has shown improvements in retail appearance when chops or steaks from ES sides were compared to chops or steaks from Not-ES sides. Table 1 presents these comparisons of retail appearance characteristics of steaks and roasts from ES and Not-ES sides used in

this study. No significant differences (P>.05) were observed between top round or porterhouse steaks from ES and Not-ES treatments for muscle color, surface discoloration or overall appearance. However, for seven-bone roasts, muscle color at the beginning of retail display was improved (P<.05) as a result of ES but ES did not improve the scores for surface discoloration or overall appearance. Also, ES did not extend the caselife of the retail cuts in this study. However, except for muscle color of top round steaks, steaks and roasts from each treatment received progressively lower (P<.05) scores for retail appearance characteristics as time of retail display increased. Furthermore, ES did not significantly (P>.05) affect the shrink loss of any of the retail cuts (Table 1). It is possible that ES did not improve the retail appearance characteristics of the retail cuts in this study because of procedures used in handling and cutting the roasts and steaks. Chops and steaks used in studies by Riley *et al.* (7, 8), Hall *et al.* (3) and Rouquette *et al.* (9) — in which ES cuts had more desirable retail appearance characteristics than Not-ES cuts — were handled under highly sanitary conditions, whereas, in the present study, steaks and roasts were cut under normal retail store conditions of sanitation and handling.

Microbiological evaluation of retail cuts involving ES have produced conflicting results. Raccach and Henrickson (6) and Riley *et al.* (8) suggested that ES may reduce bacterial numbers on meat; however, Gill (2), Mrigadat *et al.* (5), Hall *et al.* (3) and Butler *et al.* (1) found that ES had no significant effect on bacterial numbers. In this study, final bacteria counts from seven-bone roasts from ES sides were substantially lower numerically than were those from seven-bone roasts from Not-ES sides; however, top round steaks from ES sides had substantially higher final bacteria counts than top round steaks from Not-ES sides (Table 1).

Research has established that ES improves palatability of beef steaks (4,11,12,14,15). Table 2 presents comparisons of palatability and cooking characteristics for ribeye and sirloin steaks from ES and Not-ES sides. Sensory panel ratings and cooking characteristics for ribeye and sirloin steaks did not differ (P>.05) between treatments for juiciness, amount of connective tissue, overall tenderness, flavor desirability, overall palatability, cooking time and cooking loss. Muscle fiber tenderness ratings for sirloin steaks were increased (P<.05) as a result of ES; however, ES resulted in higher (P<.02) shear force values for ribeye steaks.

TABLE 1. COMPARISON OF CERTAIN TRAITS FOR RETAIL CUTS SUBJECTED TO RETAIL DISPLAY

		Top round steak[a]		Porterhouse steak		Seven-bone roast	
Trait	Day	ES	Not-ES	ES	Not-ES	ES	Not-ES
Muscle color[f]	0	13.5[b]	13.2[b]	14.1[b]	13.9[b]	13.5[b]	13.2[b]
	1	12.6[c]	12.4[b]	13.1[c]	12.9[c]	12.3[c]	12.0[c]
	2	10.9[d]	10.8[c]	11.6[d]	11.3[d]	10.7[d]	9.9[d]
	3	10.5[d]	10.2[c]	9.8[e]	9.8[e]	--	--
Surface discoloration[g]	0	14.9[b]	14.9[b]	14.9[b]	14.9[b]	14.9[b]	14.9[b]
	1	13.0[c]	13.0[c]	12.3[c]	12.7[c]	13.0[c]	12.7[c]
	2	9.8[d]	10.0[d]	9.9[d]	10.4[d]	10.6[d]	9.1[d]
	3	6.6[e]	7.3[e]	7.5[e]	8.0[e]	--	--
Overall appearance[h]	0	14.5[b]	14.3[b]	14.6[b]	14.5[b]	14.4[b]	14.3[b]
	1	12.7[c]	12.5[c]	12.4[c]	12.5[c]	12.7[c]	12.3[c]
	2	9.7[d]	10.0[d]	9.4[d]	9.9[d]	10.2[d]	8.6[d]
	3	6.3[e]	7.2[e]	6.3[e]	7.1[e]	--	--
Bacterial count, $\log_{10}$	0	3.1	2.9	4.5	4.0	3.5	4.6
	2	4.4	4.6	7.5	6.1	5.4	7.9
	3	6.1	4.7	8.3	8.2	---	---
Shrink loss, %	2	---	---	---	---	0.80	0.79
	3	2.83	3.31	2.52	2.30	---	---

[a]Means for the same retail cut not underscored by a common line are not different (P> .05) by paired-t distribution. Bacterial counts were not statistically analyzed.

[b,c,d,e]Means in the same column for the same trait with a common superscript letter are not different (P>.05).

[f]15 = bright cherry red; 1 = extremely dark brown.

[g]15 = no surface discoloration; 1 = total surface discoloration.

[h]15 = extremely desirable; 1 = extremely undesirable.

TABLE 2. COMPARISONS OF PALATABILITY AND COOKING CHARACTERISTICS FOR STEAKS FROM ELECTRICALLY STIMULATED AND UNTREATED (NOT-ES) SIDES

Characteristics	Electrically stimulated		Untreated (Not-ES)		Level of probability[a]
	Mean	(S.D.)	Mean	(S.D.)	
Ribeye steak					
Juiciness[b]	5.7	(0.54)	5.7	(0.55)	NS
Muscle fiber tenderness[b]	6.4	(0.42)	6.5	(0.66)	NS
Connective tissue amount[c]	7.5	(0.31)	7.5	(0.26)	NS
Overall tenderness[b]	6.5	(0.49)	6.6	(0.65)	NS
Flavor[b]	6.3	(0.42)	6.3	(0.41)	NS
Overall palatability[b]	6.3	(0.48)	6.4	(0.56)	NS
Warner-Bratzler shear force, lb	8.2	(1.70)	7.3	(1.39)	P<0.02
Cooking time, min	25.45	(3.99)	24.00	(3.47)	NS
Cooking loss, %	26.88	(4.48)	25.59	(3.66)	NS
Sirloin steak					
Juiciness[b]	5.0	(0.63)	4.7	(0.68)	NS
Muscle fiber tenderness[b]	5.8	(0.65)	5.5	(0.77)	P<0.05
Connective tissue amount[c]	7.3	(0.48)	7.2	(0.43)	NS
Overall tenderness[b]	5.8	(0.69)	5.6	(0.81)	NS
Flavor[b]	5.9	(0.49)	5.8	(0.51)	NS
Overall palatability[b]	5.7	(0.69)	5.4	(0.79)	NS
Warner-Bratzler shear force, lb	10.6	(3.02)	10.4	(2.47)	NS
Cooking time, min	32.05	(4.66)	33.75	(4.56)	NS
Cooking loss, %	27.42	(3.25)	28.63	(2.94)	NS

[a]Probability that the difference between treatments was statistically significant as determined by paired-t distribution. P>.05 was defined as nonsignificant (NS).

[b]Means based on eight-point descriptive scales (8 = extremely juicy, tender or desirable; 1 = extremely dry, tough or undesirable).

[c]Means based on an eight-point rating scale (8 = none; 1 = abundant).

Presented in Table 3 are comparisons of palatability and cooking characteristics for roasts from ES and Not-ES sides. Sensory panel ratings, Warner-Bratzler shear force values and cooking loss percentages were not significantly (P>.05) different between treatments for bottom round roasts; however, English cut roasts from ES sides had lower sensory panel ratings for amount of connective tissue (P<.03), overall tenderness (P<.008) and overall palatability (P<.04) than did English cut roasts from Not-ES sides. McKeith *et al.* (4) reported that ES had little effect on the major muscles of the beef chuck. It is possible that the combination of ES and cooking method had a negative effect on the palatability of the English roasts. Further studies are needed to determine the combined effects of ES and cooking methods on the palatability of meat.

Tenderness differences between ES and Not-ES treatments in this study were never different enough to be detected by both sensory panel and Warner-Bratzler shear machine. Savell *et al.* (12) suggested that beef from ES and Not-ES sides will be equally tender at some postmortem time with the time being determind by the inherent tenderness of the beef. These researchers also suggested that ES appears to increase the tenderness of meat if its initial tenderness would be unacceptable and that ES does not appear to affect the tenderness of meat if its initial tenderness level would be acceptable (12). The initial tenderness of beef steaks and roasts from Not-ES Average Choice, Yield Grade 3 beef carcasses which were aged for 16 days would usually be expected to be acceptable. Therefore, it was not unexpected that the palatability of the beef used in this study was not benefitted further from ES; it is becoming increasingly clear that ES will not improve tenderness of beef that is already tender.

In conclusion, weight loss of vacuum packaged beef subprimal cuts was not affected by whether or not sides had been electrically stimulated; ES did not alter appearance characteristics of beef retail cuts and tenderness of steaks and roasts was largely unaffected by the use of ES.

Acknowledgments

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TABLE 3. COMPARISONS OF PALATABILITY AND COOKING CHARACTERISTICS FOR ROASTS FROM ELECTRICALLY STIMULATED AND UNTREATED (NOT-ES) SIDES.

	Electrically stimulatd		Untreated (Not-ES)		Level of probability[a]
	Mean	(S.D.)	Mean	(S.D.)	
Bottom round roast					
Juiciness[b]	5.2	(0.77)	5.4	(0.54)	NS
Muscle fiber tenderness[b]	5.9	(0.58)	5.7	(0.64)	NS
Connective tissue amount[c]	5.2	(0.43)	5.1	(0.46)	NS
Overall tenderness[b]	5.1	(0.41)	4.9	(0.59)	NS
Flavor[b]	5.5	(0.39)	5.4	(0.32)	NS
Overall palatability[b]	5.0	(0.48)	4.8	(0.56)	NS
Warner-Bratzler shear force, lb	13.0	(2.87)	13.0	(2.84)	NS
Cooking time, min	80.70	(6.54)	77.35	(8.71)	P<0.05
Cooking loss, %	24.86	(2.34)	25.02	(2.82)	NS
English roast					
Juiciness[b]	4.7	(0.86)	4.5	(1.02)	NS
Muscle fiber tenderness[b]	4.5	(0.51)	4.7	(0.54)	NS
Connective tissue amount[c]	5.0	(0.74)	5.3	(0.62)	P<0.03
Overall tenderness[b]	4.3	(0.58)	4.5	(0.51)	P<0.008
Flavor[b]	4.9	(0.49)	5.0	(0.46)	NS
Overall palatability[b]	4.3	(0.52)	4.5	(0.55)	P<0.04
Warner-Bratzler shear force, lb	10.6	(1.37)	10.1	(1.19)	NS
Cooking time, min	48.65	(6.43)	48.85	(5.70)	NS
Cooking loss, %	27.71	(4.37)	29.55	(3.81)	NS

[a]Probability that the difference between treatments was statiscially significant as determined by paired-t distribution. P>.05 was defind as nonsignificant (NS).
[b]Means based on eight-point descriptive scales (8 = extremely juicy, tender or desirable; 1 = extremely dry, tough or undesirable).
[c]Means based on an eight-point rating scale (8 = none; 1 = abundant).

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PR-3935

USDA Quality Grades and the Palatability of Cooked Beef

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Summary

Taste panel ratings and shear force values from loin steaks of 1005 beef carcasses and from round steaks of 347 carcasses were used to determine relationships between USDA quality grades and palatability. Prime carcasses produced steaks that were more palatable ($P<.05$) than were those from carcasses of lower USDA quality grades in 85.7 percent of comparisons of mean panel ratings or shear force values; comparable percentages were 71.4 for Choice, 74.3 for Good, 73.2 for Standard, 94.4 for Commercial, 71.4 for Utility and 21.4 for Cutter. Across the complete range in USDA quality grades, beef from Prime, Choice and Good carcasses was much more palatable than that from Utility, Cutter and Canner carcasses and generally more palatable than that from Standard and Commercial carcasses. Among Prime, Choice, Good, and Standard grade carcasses, loin and round steaks from Prime carcasses were superior to those from Choice, Good and Standard carcasses. Beef from the Choice grade was more palatable than that from the Standard grade but the difference in palatability of Choice and Good beef was of minor consequence. Evidence is presented which suggests that beef in the present Good grade could be added to that in the present Choice grade with very minimal effects on the palatability characteristics of beef in the newly created group. Within the carcass maturity range encompassing those carcasses which are youthful enough (A + B maturity groups) to qualify for the Prime, Choice, Good, and Standard grades, grade predicted flavor, tenderness, and overall palatability of loin steaks with 30 to 35 percent accuracy, but could not explain more than 8 percent of the flavor, tenderness, overall palatability, and/or shear force value differences among broiled top round, bottom round, or eye of round steaks.

Introduction

A system of grades for cattle and for beef provides a mechanism for reflecting consumer preferences back through the marketing system to producers. Quality grades are useful to wholesalers, retailers, and consumers if they successfully segment beef carcasses into groups that will produce cooked beef cuts with similar palatability (flavor, juiciness, tenderness, etc.) attributes. Grading, as it applies to beef, is a process of sorting our heterogeneous supply of beef carcasses into smaller segments (grades) each of which includes beef having a sufficiently narrow range of grade-determining factors such that individual carcasses in the same grade have a high degree of interchangeability.

For purposes of this report, it is assumed — as stated in the present US beef quality grade standards — that the quality grades are supposd to identify differences in the palatability of the cooked product. Based on that premise, two approaches could be used in the development of the standards on which beef is graded. In the first approach, it could be assumed that consumers are only interested in being able to differentiate between beef that is or is not "Acceptable" in cooked-palatability — that is, in having assurance at the time of purchase that the cooked beef will be either "Acceptable" or "Unacceptable" in flavor, juiciness, tenderness and overall palatability. Although this concept appears simple, its supposed simplicity rests on being able to find an "acceptability" concensus among all potential consumers of beef.

The second possible approach to developing the standards for grading beef would be to assume that there are consumers who are (a) more discriminating than the average and (b) willing and able to pay premiums for beef of "better than average" palatability and that there are consumers who are (a) less discriminating than the average and (b) unwilling and/or unable to pay a price for beef that would be representative of beef with "average" palatability. Using that premise, a body of several entities (grades) arranged in a graded series would be appropriate for use in sorting available supplies of beef into categories that differed in relative desirability.

The present study determined relationships between cooked beef palatability attributes and USDA quality grades using both statistical and non-statistical procedures and both of the previously defined approaches to grading.

Experimental Procedure

Beef carcasses ($n = 1005$) were selected from eight packing plants in six states. Carcasses were chosen by concensus of a committee of three persons (one selector was from Texas A&M University; two selectors were from the USDA). The experimental design was based on (a) degree of marbling (Moderately Abundant through Practically Devoid) and (b) overall carcass maturity (A, B, C and E). Grades and grade relationships discussed in this paper are based on the current (in 1981) USDA beef carcass quality grading standards. Loins were obtained from all 1005 of the carcasses; rounds were obtained from 347 of the carcasses. A loin or a hindquarter from each selected carcass was shipped to Texas A&M University; on the 10th to 14th day postmortem, loin and/or round steaks were cut, wrapped and frozen. At the time of cutting, four of the steaks from each strip-loin were assigned to Texas A&M University; four other steaks from each strip-loin were air-transported to one of three cooperating laboratories (Iowa State University, Colorado State University, or the Meat Science Research Laboratory of USDA). Texas A&M University

and each cooperator selected 10 sensory panel members and trained them to evaluate cooked beef palatability. Loin steaks were evaluated at all four locations; round steaks were evaluated only at Texas A&M University.

Loin and top round steaks were broiled to an internal temperature of 70°C and warm samples were independently scored by each member of the appropriate sensory evaluation panels for flavor, juiciness, tenderness, amount of connective tissue and overall palatability by use of 8-point rating scales (8 = extremely desirable in flavor, extremely juicy, extremely tender, no connective tissue and extremely desirable in overall palatability, respectively; 1 = extremely undesirable in flavor, extremely dry, extremely tough, an abundant amount of connective tissue and extremely undesirable in overall palatability, respectively). Warner-Bratzler shear force measurements were performed in duplicate on four cores (0.5 inch in diameter) from loin steaks and top round steaks at the time of sensory panel analysis and on bottom round and eye of round steaks that were broiled to an internal temperature of 70°C at another time.

Data were analyzed using regression analyses, analyses of variance, and mean separation analyses. In addition, certain data were grouped and/or sorted into relative-magnitude groupings to facilitate evaluations of two concepts of grading.

Results and Discussion

Mean sensory panel ratings for loin and top round steaks are presented in Tables 1 and 2, respectively, and shear force values for loin, top round, bottom round, and eye of round steaks are presented in Table 3. Prime carcasses produced steaks that were more palatable ($P<.05$) than were those from carcasses of lower USDA quality grades in 85.7 percent of the comparisons of mean sensory panel ratings or shear force values in Tables 1, 2 and 3; comparable percentages were 71.4 for Choice, 74.3 for Good, 73.2 for Standard, 94.4 for Commercial, 71.4 for Utility and 21.4 for Cutter. Across the complete range of USDA quality grades, a higher grading carcass will, on the average, yield loin and round steaks that are more palatable than will a carcass of a lower grade.

Among USDA quality grades comprised solely of carcasses that are in the A + B maturity groups (Prime, Choice, Good and Standard) and which are normally directed to block beef and food service (HRI) trades, Prime carcasses produced steaks that were more palatable ($P<.05$) than did carcasses of lower USDA quality grades in 69 percent of comparisons of mean sensory panel ratings or shear force values; comparable percentages were 42.9 for Choice and 35.7 for Good. Prime carcasses produced steaks that were more desirable ($P<.05$) than were those from carcasses of lower USDA quality grades in 100.0 percent of comparisons for flavor, juiciness, tenderness and overall palatability, in 16.7 percent of comparisons for amount of connective tissue, and in 33.0 percent of comparisons of shear force value. Choice carcasses produced steaks that were more desirable ($P<.05$) than were those from Good or Standard carcasses in 50.0 percent of comparisons for flavor, juiciness, tenderness and overall palatability, in 25.0 percent of comparisons for amount of connective tissue and in 37.5 percent of comparisons of shear force value. Good carcasses produced steaks that were more desirable ($P<.05$) than were those from Standard carcasses in 50.0 percent of comparisons for flavor, amount of connective tissue, tenderness and overall palatability, 0.0 percent of comparisons for juiciness and 25.0 percent of comparisons of shear force values. Except for juiciness, steaks from Prime carcasses are superior in mean panel ratings to those from carcasses in the lower grades about 83 percent of the time, whereas steaks from Choice (compared to those from Good and Standard carcasses) and from Good (compared to those from Standard carcasses) carcasses are superior in mean panel ratings to steaks from carcasses in the lower grades about 45 percent and 60 percent of the time, respectively.

Percentage incidence of loin steaks in specified sensory panel rating ranges, stratified by USDA quality grade, is presented in Table 4. Data were grouped

TABLE 1. MEAN SENSORY PANEL RATINGS FOR LOIN STEAKS FROM CARCASSES ASSIGNED TO EACH USDA QUALITY GRADE

USDA quality grade	Number of carcasses	Sensory panel rating[h]				
		Flavor	Juiciness	Amount of connective tissue	Tenderness	Overall palatability
Prime	108	6.08[a]	5.50[a]	6.61[a]	6.41[a]	6.02[a]
Choice	268	5.80[b]	5.09[d]	6.73[a]	6.14[b]	5.71[b]
Good	87	5.53[c]	4.87[e]	6.62[a]	5.73[c]	5.33[c]
Standard	137	4.97[e]	4.75[e]	6.16[b]	5.01[e]	4.63[e]
Commercial	189	5.21[d]	5.40[ab]	5.85[c]	5.26[d]	4.93[d]
Utility	156	4.50[f]	5.13[cd]	5.29[d]	4.31[f]	3.99[f]
Cutter	52	3.88[g]	5.29[bc]	4.53[e]	3.84[g]	3.39[g]
Canner	8	3.42[g]	5.03[de]	4.31[e]	3.33[g]	2.84[g]

[abcdefg]Means in the same column followed by a common superscript letter are not significantly different ($P>.05$).

[h]8 = extremely desirable in flavor, extremely juicy, no connective tissue, extremely tender and extremely desirable in overall palatability; 1 = extremely undesirable in flavor, extremely dry, abundant connective tissue, extremely tough and extremely undesirable in overall palatability.

TABLE 2. MEAN SENSORY PANEL RATINGS FOR TOP ROUND STEAKS FROM CARCASSES ASSIGNED TO EACH USDA QUALITY GRADE

USDA quality grade	Number of carcasses	Sensory panel rating[f]				
		Flavor	Juiciness	Amount of connective tissue	Tenderness	Overall palatability
Prime	33	5.25[a]	5.70[a]	5.73[a]	5.90[a]	5.32[a]
Choice	77	4.66[b]	5.04[bc]	5.57[a]	5.41[b]	4.74[b]
Good	28	4.79[b]	4.81[c]	5.51[a]	5.23[b]	4.65[b]
Standard	38	4.77[b]	4.86[c]	5.39[a]	5.06[b]	4.66[b]
Commercial	79	4.08[c]	5.28[b]	4.52[b]	4.40[c]	3.84[c]
Utility	63	4.10[c]	5.08[bc]	4.23[c]	3.81[d]	3.53[d]
Cutter	26	3.57[d]	5.31[b]	3.32[d]	3.18[e]	2.75[e]
Canner	3	3.51[d]	4.68[c]	2.32[e]	2.22[e]	2.08[e]

[abcde]Means in the same column followed by a common superscript letter are not significantly different (P>.05).

[f]8 = extremely desirable in flavor, extremely juicy, no connective tissue, extremely tender and extremely desirable in overall palatability; 1 = extremely undesirable in flavor, extremely dry, abundant connective tissue, extremely tough and extremely undesirable in overall palatability.

TABLE 3. MEAN SHEAR FORCE VALUES FOR LOIN, TOP ROUND, BOTTOM ROUND AND EYE OF ROUND STEAKS

USDA quality grade	Shear force value (lb)[e]							
	Loin		Top round		Bottom round		Eye of round	
	N	Mean	N	Mean	N	Mean	N	Mean
Prime	108	6.66[a]	33	10.59[a]	33	12.34[a]	33	11.43[a]
Choice	268	7.45[b]	77	10.31[a]	76	13.27[a]	76	11.62[a]
Good	87	8.47[c]	28	11.20[a]	28	13.11[a]	28	12.51[ab]
Standard	137	10.50[d]	38	11.46[a]	38	13.71[a]	38	12.89[b]
Commercial	189	8.85[c]	79	13.24[b]	79	16.16[b]	79	14.68[c]
Utility	156	11.33[d]	63	13.96[b]	63	18.09[c]	63	15.20[c]
Cutter	52	11.97[d]	26	17.61[c]	26	22.41[d]	26	17.19[c]
Canner	8	12.01[d]	3	18.94[c]	3	26.22[d]	3	17.75[c]

[abcd]Means in the same column followed by a common superscript letter are not significantly different (P>.05).

[e]Mean force in pounds required to shear a half-inch diameter core of cooked muscle.

in this manner to facilitate evaluations of usefulness of USDA quality grades for segregating carcasses into groups differeing in the likelihood that steaks would be "Desirable" vs. "Undesirable" or "Acceptable" vs. "Unacceptable" in palatability. Data in Table 4 support the hypothesis that higher grades increase the likelihood of obtaining a broiled loin steak of superior palatability. The chance of obtaining loin steaks of "Desirable" overall palatability among carcasses of different USDA quality grades was about 56 of 100 for Prime, 34 of 100 for Choice, 14 of 100 for Good, 5 of 100 for Standard, 17 of 100 for Commercial, 1 of 100 for Utility, 0 of 100 for Cutter and 0 of 100 for Canner. The probability of obtaining an "Undesirable" loin steak was zero if the carcass graded Prime (0.00), Choice (0.00) or Good (0.00); comparable probabilities were 0.05 for Standard, 0.05 for Commercial, 0.16 for Utility, 0.29 for Cutter and 0.50 for Canner.

Data in Table 4 suggest that the three highest grades of beef are essentially equivalent to each other and much more effective than other grades in assuring "acceptability" of broiled loin steaks. The probability of obtaining loin steaks of "Acceptable" palatability (based on overall palatability ratings) was 1.00 in Prime, 0.99 in Choice, 1.00 in Good, 0.77 in Standard, 0.79 in Commercial, 0.51 in Utility, 0.25 in Cutter and 0.00 in Canner. Probabilities that carcasses of each USDA quality grade would produce broiled round steaks of "Acceptable" overall palatability were about 0.94 in Prime, 0.84 in Choice, 0.86 in Good, 0.87 in Standard, 0.46 in Commercial, 0.33 in Utility, 0.12 in Cutter and 0.00 in Canner (data not presented in tabular form).

If industry desires to have a USDA quality grade for the food sevice (HRI) trade, Prime appears to fulfill that need based on the relatively high probability that broiled steaks will be superior in palatability to those from other grades (Tables 1, 2, 3, and 4). If industry desires to lower the minimum marbling requirement for the retail consumer-oriented, block beef grade (presently U.S. Choice), data in table 5 suggest that the palatability characteristics of a group created by combining beef from the U.S. Choice and U.S. Good grades is not very different from those of beef in the present U.S. Choice grade. It is unlikely that consumers would perceive any of the differences in palatability that would occur as a result of the combining of the present U.S. Choice and U.S. Good grades into a new grade group.

Differences in USDA quality grade, within full grades, were associated (data not presented in tabular form) with 30.3 percent (A maturity), 35.4 percent

TABLE 4. PERCENTAGE INCIDENCE OF "DESIRABLE", "UNDESIRABLE", "ACCEPTABLE" AND "UNACCEPTABLE" SENSORY PANEL RATINGS FOR LOIN STEAKS, STRATIFIED BY USDA QUALITY GRADE

Type of rating or value[a]	USDA quality grade	Sensory panel rating			
		Flavor	Juiciness	Tenderness	Overall palatability
"Desirable"	Prime	58.4	16.7	76.9	55.6
"Desirable"	Choice	38.8	3.0	61.2	33.6
"Desirable"	Good	21.9	1.2	39.0	13.8
"Desirable"	Standard	8.0	2.2	23.4	5.1
"Desirable"	Commercial	25.4	10.1	31.8	17.4
"Desirable"	Utility	3.9	8.3	9.0	0.6
"Desirable"	Cutter	0.0	5.8	3.8	0.0
"Desirable"	Canner	0.0	0.0	0.0	0.0
"Undesirable"	Prime	0.0	0.0	0.0	0.0
"Undesirable"	Choice	0.0	0.0	0.0	0.0
"Undesirable"	Good	0.0	0.0	0.0	0.0
"Undesirable"	Standard	1.5	0.0	4.4	5.1
"Undesirable"	Commercial	1.0	0.0	5.8	4.8
"Undesirable"	Utility	3.2	0.0	16.1	16.1
"Undesirable"	Cutter	11.6	0.0	19.2	28.8
"Undesirable"	Canner	12.5	0.0	25.0	50.0
"Acceptable"	Prime	99.1	100.0	100.0	100.0
"Acceptable"	Choice	99.3	97.0	100.0	99.3
"Acceptable"	Good	100.0	95.4	97.7	100.0
"Acceptable"	Standard	89.0	92.7	81.7	76.7
"Acceptable"	Commercial	86.3	98.9	87.9	78.8
"Acceptable"	Utility	73.1	96.8	61.5	50.6
"Acceptable"	Cutter	44.2	100.0	44.3	25.0
"Acceptable"	Canner	12.5	100.0	12.5	0.0
"Unacceptable"	Prime	0.9	0.0	0.0	0.0
"Unacceptable"	Choice	0.7	3.0	0.0	0.7
"Unacceptable"	Good	0.0	4.6	2.3	0.0
"Unacceptable"	Standard	11.0	7.3	18.3	23.3
"Unacceptable"	Commercial	13.7	1.1	12.1	21.2
"Unacceptable"	Utility	26.9	3.2	38.5	49.4
"Unacceptable"	Cutter	55.8	0.0	55.7	75.0
"Unacceptable"	Canner	87.5	0.0	87.5	100.0

[a]"Desirable" ratings were those of 6.00 or higher, "Undesirable" ratings were those of 2.99 or lower, "Acceptable" ratings were those of 4.00 or higher, "Unacceptable" ratings were those of 3.99 or lower.

(A + B maturity), 27.3 percent (C + E maturity) and 43.1 percent (A − E maturity) of the observed variation in overall palatability ratings of loin steaks and with 5.0 percent (A maturity), 7.3 percent (A + B maturity), 13.7 percent (C + E maturity) and 37.3 percent (A − E maturity) of the observed variation in overall palatability ratings for top round steaks. Grade explained about 20 percent or more of the variation in flavor, tenderness and overall palatability of loin steaks in all four ranges in carcass maturity. Among A maturity carcasses (where grade is determined essentially by marbling only) and among A + B maturity carcasses (where grade is determined in B maturity essentially by marbling and maturity) grade accounted for 20 percent or more of the variability in flavor, tenderness, overall palatability and shear force value of loin steaks but only 9 percent or less of the variability in amount of connective tissue in loin or top round steaks and of the flavor, tenderness, overall palatability and/or shear force value of top round, bottom round, and eye of round steaks (data not presented in tabular form).

Additional data (not presented here in tabular form) suggest that use of divisions finer than whole USDA quality grades (e.g., halves or thirds of grades) would not improve substantially upon the ability of the system to account for differences in eating satisfaction among either loin or round steaks.

Across the entire range of marbling and maturity encountered among beef carcasses, grades were able (data not presented in tabular form) to account for substantial proportions (37 to 43 percent) of the observed variability in overall palatability of loin and top round steaks and reasonably high percentages (22 to 31 percent) of the variation in shear force values for loin, top round, bottom round, and eye of round steaks. Within the maturity range encompassing those carcasses which are youthful enough (A + B maturity group) to qualify for the Prime, Choice, Good and Standard grades, grade predicted flavor, tenderness, and overall palatability of loin steaks with 30 to 35 percent accuracy yet could explain no more than 8 percent of the observed differences in the flavor, tenderness, overall palatability ratings, and/or

TABLE 5. COMPARISON OF PALATABILITY OF STEAKS FROM CARCASSES IN THE U.S. CHOICE GRADE AND THAT OF STEAKS FROM A GROUP CREATED BY COMBINING BEEF FROM THE U.S. CHOICE AND U.S. GOOD GRADES

Trait	Steak	Present Choice	Present Choice and present Good, combined[a]	Present Choice and present Good, combined[b]
Flavor rating	Loin	5.80	5.73	5.67
Juiciness rating	Loin	5.09	5.04	4.98
Amount of connective tissue rating	Loin	6.73	6.70	6.68
Tenderness rating	Loin	6.14	6.04	5.94
Overall palatability rating	Loin	5.71	5.62	5.52
Shear force value, lb.	Loin	7.45	7.70	7.96
Flavor rating	Top round	4.66	4.69	4.73
Juiciness rating	Top round	5.04	4.98	4.93
Amount of connective tissue rating	Top round	5.57	5.55	5.54
Tenderness rating	Top round	5.41	5.36	5.32
Overall palatability rating	Top round	4.74	4.72	4.70
Shear force value, lb.	Top round	10.31	10.55	10.76
Shear force value, lb.	Bottom round	13.27	13.23	13.19
Shear force value, lb.	Eye of round	11.62	11.86	12.07
Probability, "Desirable"	Loin	0.494	0.460	0.423
Probability, "Desirable"	Round	0.088	0.093	0.098
Probability, "Undesirable"	Loin	0.001	0.001	0.002
Probability, "Undesirable"	Round	0.071	0.075	0.078
Probability, "Acceptable"	Loin	0.985	0.982	0.978
Probability, "Acceptable"	Round	0.754	0.742	0.732
Probability, "Unacceptable"	Loin	0.015	0.018	0.022
Probability, "Unacceptable"	Round	0.246	0.258	0.268

[a]Means and probabilities computed from actual data, weighted by numbers of observations in each grade in this study (Choice = 268 and Good = 87).
[b]Means and probabilities computed assuming that there are equal numbers of observations in each grade (Choice = 100 and Good = 100).

shear force values among broiled top round, bottom round or eye of round steaks.

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PR-3936

Marbling, Subcutaneous Fat Thickness, and Cooked Beef Palatability

J. D. TATUM, G. C. SMITH AND Z. L. CARPENTER

Summary

Steers (n = 471) were fed identical finishing diets for 100, 130, or 160 days in a commercial feedlot. Cattle were slaughtered, carcasses were evaluted by a USDA grader, and rib steaks were cooked and used for sensory panel evaluation. Marbling had a low, but positive, relationship with all of the palatability traits; more than 90 percent of the steaks with "Slight" or higher degrees of marbling were "Desirable" in tenderness, flavor, desirability, and overall palatability. The relationships between subcutaneous fat thickness and the organoleptic properties of beef were neither linear nor additive; fat thickness levels of 0.30 to 0.40 in. provided relatively high assurance of "Desirable" palatability. Compared to marbling, fat thickness was ineffective as a predictor of cooked beef

palatability, and therefore, would appear to be an unsuitable substitute for marbling as a factor for use in determining grade. However, marbling, used in combination with a minimum subcutaneous fat thickness constraint of 0.30 in. for carcasses with a "Slight" amount of marbling, facilitated more equitable stratification of carcasses according to their expected palatability than did marbling alone.

Introduction

The USDA standards for grades of carcass beef have been revised numerous times since their promulgation in 1926; however, marbling continues to receive primary consideration for assessing quality in the current beef grading system (9).

Although research, to date, has shown a positive relationship between marbling and palatability, it has also indicated that this relationship is far from infallible. Research studies also have demonstrated that beef quality is closely related to pre-slaughter feeding (1,2,5) and that beef from young cattle finished on high-energy diets is similar in palatability despite large differences in the amount of marbling (8). Therefore, since USDA grades are applied almost exclusively to carcasses from youthful, grain-finished steers and heifers, the amount of emphasis currently placed on marbling as a value-determining carcass characteristic should be questioned. Alternatives to the use of marbling as the primary consideration for assessing the quality of beef also should be examined.

Evidence suggests that subcutaneous fat thickness may be closely associated with beef palatability. Using a rationale originally developed from research involving lamb carcasses (7), TAES researchers (2) have demonstrated that increases in subcutaneous fat thickness reduce the rate of carcass temperature decline during postmortem chilling and improve beef tenderness by lessening the extent of cold-induced toughening and by enhancing the rate and extent of postmortem muscle autolysis. Based on these results, it is logical to assume that subcutaneous fat thickness might, either alone or in combination with marbling, better identify young beef carcasses according to expected palatability of their lean than do USDA grades.

Previous investigations of the relationship between fat deposition and beef palatability have characterized the independent effects of either marbling or fat thickness on the palatability of beef, but have not addressed the interrelationships among these factors. The purpose of this study was to examine the singular and combined effects of marbling and subcutaneous fat thickness on the palatability of steaks from grain-finished steers and to determine the effectiveness of using subcutaneous fat thickness as an adjunct to, or substitute for, marbling as an indicator of beef palatability.

Experimental Procedures

Yearling and long-yearling feeder steers (n = 471), exhibiting considerable variation in management background and biological-type, were fed identical finishing diets (69.92% DM, 2.18 M cal/kg NEm, 1.37 M cal/kg NEp) for 100, 130 or 160 days in a commercial feedlot. After feeding, the cattle were slaughtered; carcasses were chilled at 1 ± 1 C and, at 24 hr postmortem, they were graded.

At 14 days postmortem, two steaks (1.25 in. thick) were removed from one wholesale rib from each carcass; these steaks were then frozen and stored at −30 F and subsequently thawed (35 F) and broiled to an internal temperature of 158 F. Samples of one of the cooked steaks were evaluated by an eight-member, trained sensory panel for juiciness, tenderness, flavor desirability and overall palatability using an 8-point, descriptive, rating scale. The second steak was used for Warner-Bratzler shear force determinations.

Data were analyzed using simple regression, analysis of variance, and response surface regression techniques. Also, steaks were assigned one of two "desirability" ratings based on each of their mean panel ratings for overall tenderness, flavor desirability, and overall palatability. Steaks with mean sensory panel ratings of 4.50 or higher were assigned a "Desirable" rating; steaks with mean sensory panel ratings lower than 4.50 were assigned an "Undesirable" rating.

Results and Discussion

Relationship Between Marbling and Cooked Beef Palatability. Previous research has consistently demonstrated only low to moderate relationships between marbling and the palatability traits of beef (3,4,6). In the present study, marbling accounted for only approximately 5, 5, 15 and 9 percent of the variation in sensory panel ratings for juiciness, tenderness, flavor desirability, and overall palatability, respectively (table 1). However, as in previous studies (3,4,6), each of the palatability traits was positively related to marbling, and each relationship was highly significant. However, the data also indicate that large differences in marbling would be required to effect a detectable change in palatability. Furthermore, the low magnitude of the coefficients of determination ($r^2 \times 100$) suggest that there may be factors, other than marbling, that are more closely associated with differences in beef palatability.

Despite the low degree of association between marbling and cooked beef palatability, marbling was relatively effective in identifying steaks with "Desirable" *vs.* "Undesirable" palatability attributes (table 2). More than 92, 99, and 92 percent of the steaks having "Slight" or higher degrees of marbling received "Desirable" sensory panel ratings for tenderness, flavor desirability, and overall palatability, respectively.

Influence of Subcutaneous Fat Thickness on Cooked Beef Palatability. Existing data regarding the relationship between fat thickness and the eating quality of meat indicate that increased subcutaneous

TABLE 1. SIMPLE REGRESSION EQUATIONS USING MARBLING[a] AS A PREDICTOR OF COOKED BEEF PALATABILITY TRAITS

Dependent variable	Statistic			Probability of significance
	Intercept	b	$r^2 \times 100$	
Juiciness	4.17	.0016	4.77	.001
Tenderness	5.24	.0018	5.30	.001
Flavor desirability	5.06	.0019	14.74	.001
Overall palatability	4.85	.0020	9.18	.001

[a]0 to 99 = practically devoid; 100 to 199 = traces; 200 to 299 = slight; 300 to 399 = small; 400 to 499 = modest; 500 to 599 = moderate; *et cetera*.

fat thickness improves the palatability of meat through its effect on the rate of postmortem chilling (2,7). TAES research (2) revealed that progressive increases in fat thickness from 0.05 in. to 0.35 in. were associated with progressively increased sarcomere length and improved beef tenderness, while subcutaneous fat thickness in excess of 0.40 in. provided no further improvement of tenderness.

In this study, steaks from carcasses with less than 0.20 in. of subcutaneous fat over the *longissimus* muscle at the 12th rib had the highest ($P<.05$) shear force values and the lowest ($P<.05$) sensory panel ratings for tenderness, flavor desirability, and overall palatability (table 3). In general, sensory panel ratings increased and shear force values decreased as subcutaneous fat thickness increased to 0.50 in.; however, differences associated with successive increases in fat thickness, between the levels of 0.20 in. and 0.50 in., usually were not of sufficient magnitude for statistical significance.

Data presented in table 4 show that more than 90 percent of steaks from carcasses with at least 0.30 in. of fat thickness received "Desirable" ratings for tenderness, flavor desirability, and overall palatability and that fat thickness in excess of 0.40 in. did not materially reduce the incidence of steaks rated as "Undesirable".

Results of this study suggest that the relationship between subcutaneous fat thickness and beef palatability is neither linear nor additive and that 0.30 to 0.40 in. of subcutaneous fat over the *longissimus* muscle at the 12th rib is sufficient to realize the maximum potential for improving beef palatability by increasing subcutaneous fat thickness.

Combined Effects of Marbling and Subcutaneous Fat Thickness on Cooked Beef Palatability. The response of beef palatability to various combinations of marbling and fat thickness was determined by response surface regression analyses to identify the best fitting plane for the relationship between subcutaneous fat thickness, marbling, and overall palatability.

When the combined effects of marbling and fat thickness were examined (data not presented in tabular or figure form), marbling had the most pronounced effect on cooked beef palatability. Overall palatability ratings increased linearly as degree of marbling increased and the rate of change in overall palatability, associated with successive increases in marbling, was consistent across all levels of fat thickness. Changes in overall palatability ratings associated with differences in subcutaneous fat thickness were negligible. The degree of colinearity between marbling and subcutaneous fat thickness was low ($r^2 = .06$). The lowest overall palatability ratings occurred when low levels of marbling were combined with subcutaneous fat levels below 0.10 and above 0.90 inches. The highest palatability ratings were observed among steaks with high levels of marbling and intermediate levels (0.30 to 0.80 in.) of subcutaneous fat.

Data presented in table 5 show the effects which variations in marbling and in fat thickness — .30 in. or more vs. less than .30 in. — have on the incidence of "Undesirable" overall palatability ratings. These data indicate that the influence of marbling on overall palatability was relatively more important than that of fat thickness and that when marbling levels were sufficiently high ("Small" or higher) or very low ("Traces" or lower), differences in fat thickness had little or no effect on palatability. However, one important finding was that steaks with "Slight" marbling and fat thickness levels of 0.30 in. or more

TABLE 2. PERCENTAGES OF STEAKS RECEIVING "DESIRABLE" *VERSUS* "UNDESIRABLE" RATINGS FOR TENDERNESS, FLAVOR DESIRABILITY AND OVERALL PALATABILITY STRATIFIED ACCORDING TO USDA MARBLING SCORE

USDA marbling score[b]	No. of observations	Tenderness[a]		Flavor desirability[a]		Overall palatability[a]	
		"Desirable," %	"Undesirable," %	"Desirable," %	"Undesirable," %	"Desirable," %	"Undesirable" %
Moderate or higher	14	92.9	7.1	100.0	.0	100.0	.0
Modest	59	98.3	1.7	100.0	.0	100.0	.0
Small	121	95.9	4.1	99.2	.8	94.2	5.8
Slight	242	93.0	7.0	99.6	.4	92.5	7.5
Traces or lower	35	85.7	14.3	97.1	2.9	80.0	20.0

[a]"Desirable" = steaks with mean sensory panel ratings of 4.50 or higher; "undesirable" = steaks with mean sensory panel ratings lower than 4.50.
[b]Based on descriptions included in USDA beef grade standards (9) and assigned by USDA personnel.

TABLE 3. LEAST-SQUARES MEANS FOR PALATABILITY TRAITS STRATIFIED ACCORDING TO SUBCUTANEOUS FAT THICKNESS GROUP[a]

Subcutaneous fat thickness group	No. of observations	Sensory panel rating				Shear force,[c] lb
		Juiciness	Tenderness	Flavor desirability	Overall palatability	
0.10 to 0.19 in.	12	4.58[de]	5.21[e]	5.21[f]	4.90[e]	11.0[d]
0.20 to 0.29 in.	73	4.40[e]	5.77[d]	5.57[e]	5.35[d]	9.5[e]
0.30 to 0.39 in.	102	4.70[d]	5.78[d]	5.60[e]	5.48[d]	9.5[e]
0.40 to 0.49 in.	98	4.69[d]	5.84[d]	5.70[de]	5.53[d]	9.4[e]
0.50 to 0.59 in.	67	4.64[d]	5.79[d]	5.56[e]	5.43[d]	9.4[e]
0.60 to 0.69 in.	49	4.71[d]	5.76[d]	5.74[de]	5.57[d]	9.5[e]
0.70 to 0.79 in.	40	4.72[d]	5.70[de]	5.75[de]	5.50[d]	9.7[de]
0.80 in. or more	30	4.84[d]	5.64[de]	5.82[d]	5.51[d]	9.7[de]

[a]Maturity was held constant by analysis of covariance procedures.

[b]8 = extremely juicy, extremely tender, extremely desirable or extremely palatable, respectively; 1 = extremely dry, extremely tough, extremely undesirable or extremely unpalatable, respectively.

[c]Warner-Bratzler shear force determinations made with 0.50 in. cores.

[d,e,f]means in the same column bearing a common superscript letter are not different (P>.05).

TABLE 4. PERCENTAGES OF STEAKS RECEIVING "DESIRABLE" VERSUS "UNDESIRABLE" RATINGS FOR TENDERNESS, FLAVOR DESIRABILITY AND OVERALL PALATABILITY STRATIFIED ACCORDING TO SUBCUTANEOUS FAT THICKNESS GROUP

Subcutaneous fat thickness group	No. of observations	Tenderness[a]		Flavor desirability[a]		Overall palatability[a]	
		"Desirable," %	"Undesirable," %	"Desirable," %	"Undesirable," %	"Desirable," %	"Undesirable," %
0.10 to 0.19 in.	12	66.7	33.3	100.0	.0	75.0	25.0
0.20 to 0.29 in.	73	91.7	8.3	98.6	1.4	86.1	13.9
0.30 to 0.39 in.	102	97.0	3.0	99.0	1.0	96.0	4.0
0.40 to 0.49 in.	98	92.9	7.1	99.0	1.0	94.9	5.1
0.50 to 0.59 in.	67	95.5	4.5	100.0	.0	95.5	4.5
0.60 to 0.69 in.	49	93.9	6.1	100.0	.0	89.8	10.2
0.70 to 0.79 in.	40	97.5	2.5	100.0	.0	97.5	2.5
0.80 in. or more	30	93.3	6.7	100.0	.0	96.7	3.3

[a]"Desirable" = streaks with mean sensory panel ratings of 4.50 or higher; "undesirable" = steaks with mean sensory panel ratings lower than 4.50.

TABLE 5. PERCENTAGES OF STEAKS RECEIVING "DESIRABLE" *VERSUS* "UNDESIRABLE" OVERALL PALATABILITY RATINGS STRATIFIED ACCORDING TO USDA MARBLING SCORE AND SUBCUTANEOUS FAT THICKNESS GROUP

USDA marbling score[b]	Subcutaneous fat thickness group[a]			
	0.30 in. or higher		0.29 in. or lower	
	"Desirable," %	"Undesirable," %	"Desirable," %	"Undesirable," %
Moderate or higher	100.0	.0	100.0	.0
Modest	100.0	.0	100.0	.0
Small	94.3	5.7	93.8	6.2
Slight	95.3	4.7	81.6	18.4
Traces or lower	81.8	18.2	76.9	23.1

[a]Subcutaneous fat thickness groupings were based on results of data presented in table 4.

[b]Based on descriptions included in USDA beef grade standards (9) and assigned by USDA personnel.

(currently graded US Good) and steaks with "Small" marbling (currently graded US Choice) received similar percentages of "Desirable" *vs.* "Undesirable" overall palatability ratings. Furthermore, steaks with "Slight" marbing and fat thickness levels of 0.29 in. or less (currently graded US Good) and steaks with "Traces" or lower marbling (currently graded US Standard) also received similar percentages of "Desirable" *vs.* "Undesirable" ratings. Therefore, if the fundamental objective of USDA quality grading is to segment carcasses into groupings having similar levels of palatability, it would appear justifiable to include carcasses with "Slight" marbling in the Choice grade, provided they had at least 0.30 in. thickness of subcutaneous fat, and to combine carcasses with "Slight" marbling and less than 0.30 in. fat thickness in a grade with those now graded Standard.

Under the conditions of this study, marbling had a low, but positive, relationship with all of the palata-

bility traits of beef — more than 90 percent of the steaks with "Slight" or higher degrees of marbling were "desirable" in overall tenderness, flavor desirability, and overall palatability. The relationships between subcutaneous fat thickness and the organoleptic properties of beef were neither linear nor additive; fat thickness levels of 0.30 to 0.40 in. provided relatively high assurance of "Desirable" palatability. Compared to marbling, fat thickness was ineffective as a predictor of cooked beef palatability and, therefore, would appear to be an unsuitable substitute for marbling. However, marbling, used in combination with a minimum fat thickness constraint of 0.30 in. for carcasses with a "Slight" amount of marbling, facilitated more equitable stratification of carcasses according to their expected palatability than did marbling used alone.

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PR-3937

Comparison of Subcutaneous Fat Thickness, Marbling, and Quality Grade for Predicting Palatability of Beef

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Summary

Data from 254 yearling steers, which had been either grass-fed (0 days of feeding) or fed high concentrate diets for 30 to 160 days, were used to study subcutaneous fat thickness as an alternative method for grading beef carcasses. Use of subcutaneous fat thickness to assign carcasses to three expected-palatability groups, using fat thickness categories of 0.19 in. or less, 0.20 in. to 0.39 in. and 0.40 in. or greater, was at least equivalent to, and perhaps slightly more precise than, the use of USDA quality grades for grouping the carcasses according to expected eating quality of their rib steaks. As fat thickness of carcasses from cattle fed 90 to 160 days increased from 0.09 in. or less up to 0.39 in., there were progressive increases in palatability of cooked beef. However, deposition of subcutaneous fat in quantities greater than 0.39 in. resulted in no further improvement in cooked beef palatability.

Introduction

Recently, there have been numerous efforts to identify alternative systems for segmenting the beef supply into expected-palatability groupings. It has been suggested (8) that a specific time-on-feed period and/or subcutaneous fat thickness may be possible adjuncts to, or substitutes for, the present method (maturity, marbling, quality grade) of predicting beef palatability.

Several researchers (1, 4, 6, 11) have reported that beef from cattle that have been fed a high-concentrate diet for a specified period of time will be acceptable in palatability, irrespective of its quality grade. Although the time-on-feed conept appears to be valid, complications would arise in monitoring such a system that would greatly deter its usefulness for grading or palatability prediction on a national basis.

Fattening is one of the consequences of feeding a high-energy diet to cattle. For centuries, fattening has been thought to improve the palatability of beef. The mechanism by which fattening improved tenderness was partially clarified when it was discovered (9) that increased thickness of subcutaneous fat on lamb caused carcasses to chill more slowly, increased enzyme activity, and lessened sarcomere shortening. Subsequent investigations (2, 3, 5, 7, 10, 12) have also substantiated and partially characterized the relationship between tenderness and subcutaneous fat thickness in beef. That research has generally shown that 0.24 in. to 0.39 in. of subcutaneous fat thickness is sufficient to assure that beef from young cattle will be tender; however, the usefulness of this carcass trait for grading purposes has not been fully explored. As compared with the present system of quality grading in which marbling is used as the basis for reflecting differences in fatness, an approach which gives consideration to fatness based on thickness of subcutaneous fat could (1) be more easily and uniformly applied and (2) would be easier to relate to grades for slaughter cattle. In the present study, usefulness of subcutaneous fat thickness was compared with USDA grade for predicting palatability of rib steaks.

Experimental Procedure

Yearling steers (n = 254) that had never been fed

grain, or that had been fed grain for 30 to 160 days, were obtained from a number of sources (4); included were cattle of Brahman, British (Shorthorn, Angus, Hereford), continental European (Charolais, Maine-Anjou, Simmental, Limousin) and dairy (Holstein, Jersey, Brown Swiss) breeding and crosses of most of these breeds. Grass-fed steers (0 day time-on-feed) were from two sources (La. Agr. Expt. Sta., Homer, LA; Texas Agr. Expt. Sta., Overton, TX) and were maintained entirely on millet-bermudagrass or coastal bermudagrass pastures until slaughter. Grain-fed steers (30, 60, 90, 100, 130, 160 days time-on-feed) were from four sources (La. Agr. Expt. Sta., Homer, LA; Texas Agr. Expt. Sta., Overton, TX; Monfort of Colorado, Gilchrest, CO; Harrell Cattle Company, Gonzales, TX) and were fed diets of generally similar energy-density (1.52 to 1.58 Mcal/kg NE_m, expressed on a 100 percent dry matter basis) for the designated periods of time.

Upon termination of each feeding period, the steers were slaughtered conventionally and, at 24 hr postmortem, yield and quality grade (USDA, 1975) data were obtained. Ribs were aged for 14 to 16 days postmortem at 2 ± 1°C, and two rib steaks (3.2 cm thick) were cut from the loin end of the rib, frozen at −34°C, and stored at −20°C. These steaks were later broiled and used for sensory panel evaluations of palatability using 8-point descriptive scales (8 = extremely juicy, extremely tender, no detectable connective tissue, extremely desirable flavor, and extremely desirable overall palatability) or for Warner-Bratzler shear force determinations.

Results and Discussion

Data presented in Table 1 indicate that, in general, sensory panel ratings increased and shear force values decreased as marbling score increased. Steaks from carcasses with "modest" or more marbling received higher ($P<0.05$) ratings for juiciness, tenderness, flavor desirability and overall palatability and had lower ($P<0.05$) shear force values than did steaks with "slight-minus", "traces" or "practically devoid" degrees of marbling. No significant differences were observed in any of the palatability attributes among steaks from carcasses with "small", "slight-plus", or "slight-typical" degrees of marbling.

Data presented in Table 2 show that steaks from Standard carcasses received the lowest ($P<0.05$) ratings for all of the palatability attributes except juiciness. Steaks from Choice carcasses received the highest ($P<0.05$) ratings for juiciness, flavor desirability, and overall palatability and had the lowest ($P<0.05$) shear force values; however, steaks from Good carcasses were comparable to steaks from Choice carcasses in tenderness and organoleptically detectable connective tissue.

Steaks from Choice carcasses received the highest percentages of "very desirable" ratings and the lowest percentages of "undesirable" ratings for overall tenderness, flavor desirability, and overall palatability (Table 3). The highest percentages of "undesir-

TABLE 2. MEAN VALUES FOR PALATABILITY ATTRIBUTES STRATIFIED ACCORDING TO USDA QUALITY GRADE

	USDA quality grade[a]		
Palatability attribute	Choice	Good	Standard
Number of observations	74	61	115
Juiciness[b]	5.18[f]	4.94[g]	4.82[g]
Myofibrillar tenderness[c]	5.93[f]	5.60[f]	5.11[g]
Connective tissue amount[d]	6.74[f]	6.70[f]	6.34[g]
Overall tenderness[c]	5.84[f]	5.49[f]	4.96[g]
Flavor desirability[e]	5.74[f]	5.51[g]	5.15[h]
Overall palatability[e]	5.59[f]	5.20[g]	4.70[h]
Shear force, lb	9.26[f]	11.66[g]	13.94[h]

[a]USDA (1975) grade standards (13).

[b]8 = extremely juicy; 1 = extremely dry.

[c]8 = extremely tender; 1 = extremely tough.

[d]8 = none; 1 = abundant.

[e]8 = extremely desirable; 1 = extremely undesirable.

[f,g,h]Means in the same row bearing a common superscript letter are not significantly ($P>.05$) different.

TABLE 1. MEAN VALUES FOR PALATABILITY ATTRIBUTES STRATIFIED ACCORDING TO MARBLING GROUP

	USDA marbling score group[a]							
Palatability attribute	8	7	6	5	4	3	2	1
Number of observations	41	37	22	20	20	61	31	22
Juiciness[b]	5.31[f]	5.08[fg]	4.89[gh]	5.16[fg]	4.77[gh]	4.75[h]	4.95[gh]	4.86[gh]
Myofibrillar tenderness[c]	6.08[f]	5.77[f]	5.67[fg]	5.94[f]	5.22[gh]	5.29[g]	4.72[h]	5.07[gh]
Connective tissue amount[d]	6.75[f]	6.76[f]	6.80[f]	6.77[f]	6.53[fg]	6.45[fg]	6.15[g]	6.28[g]
Overall tenderness[c]	5.96[f]	5.71[f]	5.57[fg]	5.84[f]	5.08[gh]	5.15[g]	4.55[h]	4.94[gh]
Flavor desirability[e]	5.83[f]	5.72[fg]	5.54[fgh]	5.60[fgh]	5.39[ghi]	5.28[hij]	4.98[j]	5.00[ij]
Overall palatability[e]	5.77[f]	5.44[f]	5.30[f]	5.49[f]	4.82[g]	4.84[g]	4.50[g]	4.54[g]
Shear force lb	8.62[f]	10.01[fg]	11.40[gh]	11.53[gh]	11.88[gh]	13.47[hi]	15.06[i]	14.00[hi]

[a]8 = modest and higher; 7 = small; 6 = slight-plus; 5 = slight-average; 4 = slight-minus, 3 = traces-average and traces-plus; 2 = pratically devoid-plus and traces-minus; 1 = practically devoid-average and lower.
USDA (1975) grade standards (13).

[b]8 = extremely juicy; 1 = extremely dry.

[c]8 = extremely tender; 1 = extremely tough.

[d]8 = none; 1 = abundant.

[e]8 = extremely desirable; 1 = extremely undesirable.

[f,g,h,i,j]Means in the same row bearing a common superscript letter are not significantly ($P>.05$) different.

TABLE 3. FREQUENCY PERCENTAGES OF STEAKS WITHIN EACH OF THREE LEVELS OF OVERALL TENDERNESS, FLAVOR DESIRABILITY AND OVERALL PALATABILITY STRATIFIED ACCORDING TO USDA QUALITY GRADE

	USDA quality grade[a]		
	Choice	Good	Standard
Number of observations	74	61	115
Overall tenderness[b]			
"Very desirable"	50.0	41.0	23.5
"Desirable"	45.9	41.0	46.9
"Undesirable"	4.1	18.0	29.6
Flavor desirability[b]			
"Very desirable"	44.6	24.6	11.3
"Desirable"	52.7	65.6	71.3
"Undesirable"	2.7	9.8	17.4
Overall palatability[b]			
"Very desirable"	36.5	24.6	8.7
"Desirable"	52.7	54.1	56.5
"Undesirable"	10.8	21.3	34.8

[a]USDA (1975) grade standards (13).

[b]"Very desirable" = mean sensory panel ratings of 6.00 or higher; "Desirable" = mean sensory panel ratings of 4.50 to 5.99; "Undesirable" = mean sensory panel ratings lower than 4.50.

able" ratings for the same three palatability attributes were observed for steaks from the lowest quality (Standard) carcasses.

It has been postulated that categorizing beef carcasses according to subcutaneous fat thickness might serve as effectively as quality grading for segregating beef into palatability groups (8). To test the validity of that hypothesis, data of the present study were examined using the complete population of rib steaks and, subsequently, using only those steaks from cattle in specified time-on-feed strata. For the complete population (n = 254) sensory panel ratings generally increased and shear force values generally decreased as fat thickness of the carcass from which the steaks were obtained increased; however, no significant improvement in palatability of steaks was observed in association with fat thicknesses greater than 0.49 in. (Table 4). Steaks from carcasses with at least 0.40 in. of subcutaneous fat thickness received higher ($P<0.05$) ratings for tenderness, connective tissue amount, flavor desirability, and overall palatability and had lower ($P<0.05$) shear force values than did steaks from carcasses that had less than 0.20 in. of fat thickness. Steaks from carcasses with less than 0.10 in. of fat thickness received the lowest ($P<0.05$) ratings for connective tissue amount, overall tenderness, flavor desirability, and overall palatability and had the greatest ($P<0.05$) resistance to shear force.

Among carcasses (n = 97) with at least 0.40 in. of subcutaneous fat, 96 percent, 99 percent and 90 percent were rated at least "desirable" in overall tenderness, flavor, and overall palatability, respectively (Table 5). Almost 63 percent of the steaks from carcasses with less than 0.10 in. of fat thickness were rated "undesirable" in overall palatability, while only about 10 percent of the steaks from carcasses with at least 0.40 in. of subcutaneous fat received "undesirable" overall palatability ratings.

Analyses were conducted to determine the magnitude of palatability differences among steaks from carcasses in three fat thickness groups (Table 6). Except for juiciness ratings, consistent and statistically significant sensory panel and shear force differences were observed among steaks from carcasses in the three fat thickness groups. In addition, steaks from carcasses with at least 0.40 in. of subcutaneous fat thickness received the highest percentages of "very desirable" ratings and the lowest percentages of "undesirable" ratings for overall tenderness, flavor desirability and overall palatability, whereas opposite results were observed for steaks from carcasses with less than 0.20 in. of subcutaneous fat (Table 7).

Data presented in Tables 2 and 6 suggest that the use of subcutaneous fat thickness to assign carcasses to three expected palatability groups, using fat thickness categories of 0.19 in. or less, 0.20 to 0.39 in. and

TABLE 4. MEAN VALUES FOR PALATABILITY ATTRIBUTES OF STEAKS FROM GRASS-FED STEERS AND FROM STEERS FED A HIGH-CONCENTRATE DIET FOR 30, 60, 90, 100, 130 OR 160 DAYS STRATIFIED ACCORDING TO SUBCUTANEOUS FAT THICKNESS GROUP

	Subcutaneous fat thickness group[a]							
Palatability attribute	1	2	3	4	5	6	7	8
Number of observations	32	40	40	45	41	22	14	20
Juiciness[b]	5.08^{fg}	4.84^{g}	4.79^{g}	4.83^{g}	5.02^{fg}	5.29^{f}	5.31^{f}	5.03^{fg}
Myofibrillar tenderness[c]	4.73^{h}	5.23^{gh}	5.52^{fg}	5.28^{g}	5.91^{f}	5.89^{f}	6.10^{f}	5.78^{fg}
Connective tissue amount[d]	6.00^{i}	6.33^{h}	6.68^{fg}	6.46^{gh}	6.87^{f}	6.79^{fg}	6.81^{fg}	6.75^{fg}
Overall tenderness[c]	4.53^{h}	5.07^{g}	5.39^{fg}	5.17^{g}	5.87^{f}	5.77^{f}	5.99^{f}	5.66^{fg}
Flavor desirability[e]	4.63^{i}	5.13^{h}	5.43^{g}	5.45^{g}	5.80^{fg}	5.85^{f}	5.81^{fg}	5.74^{fg}
Overall palatability[e]	4.25^{j}	4.71^{i}	5.10^{ghi}	5.01^{hi}	5.58^{fg}	5.60^{fg}	5.75^{f}	5.50^{fgh}
Shear force, lb	17.40^{i}	14.24^{h}	11.97^{g}	11.29^{fg}	9.44^{f}	9.44^{fg}	9.19^{f}	10.10^{fg}

[a]1 = 0.09 in. or less; 2 = 0.10 to 0.19 in.; 3 = 0.20 to 0.29 in.; 4 = 0.30 to 0.39 in.; 5 = 0.40 to 0.49 in.; 6 = 0.50 to 0.59 in.; 7 = 0.60 to 0.69 in. 8 = 0.70 in. or greater.

[b]8 = extremely juicy; 1 = extremely dry.

[c]8 = extremely tender; 1 = extremely tough.

[d]8 = none; 1 = abundant.

[e]8 = extremely desirable; 1 = extremely undesirable.

[f,g,h,i,j]Means in the same row bearing a common superscript letter are not significantly ($P>.05$) different.

TABLE 5. FREQUENCY PERCENTAGES OF STEAKS WITHIN EACH OF THREE LEVELS OF OVERALL TENDERNESS, FLAVOR DESIRABILITY AND OVERALL PALATABILITY STRATIFIED ACCORDING TO SUBCUTANEOUS FAT THICKNESS GROUP

	Subcutaneous fat thickness group[a]							
	1	2	3	4	5	6	7	8
Number of observations	32	40	40	45	41	22	14	20
Overall tenderness[b]								
"Very desirable"	15.6	30.0	35.0	31.1	51.2	50.0	57.2	35.0
"Desirable"	40.6	45.0	40.0	46.7	43.9	45.5	35.7	65.0
"Undesirable"	43.8	25.0	25.0	22.2	4.9	4.5	7.1	--
Flavor desirability[b]								
"Very desirable"	--	7.5	17.5	20.0	46.4	45.5	57.1	45.0
"Desirable"	62.5	70.0	72.5	75.6	51.2	54.5	42.9	55.0
"Undesirable"	37.5	22.5	10.0	4.4	2.4	--	--	--
Overal Palatability[b]								
"Very desirable"	6.2	5.0	20.0	13.3	39.0	50.0	42.9	20.0
"Desirable"	31.3	65.0	50.0	71.1	48.8	36.4	50.0	75.0
"Undesirable"	62.5	30.0	30.0	15.6	12.2	13.6	7.1	5.0

[a]1 = 0.09 in. or less; 2 = 0.10 to 0.19 in.; 3 = 0.20 to 0.29 in.; 4 = 0.30 to 0.39 in.; 5 = 0.40 to 0.49 in.; 6 = 0.50 to 0.59 in.; 7 = 0.60 to 0.60 in.; 8 = 0.70 in. or greater.

[b]"Very desirable" = mean sensory panel ratings of 6.00 or higher; "Desirable" = mean sensory panel ratings of 4.50 to 5.99; "Undesirable" = mean sensory panel ratings lower than 4.50.

TABLE 6. MEAN VALUES FOR PALATABILITY ATTRIBUTES STRATIFIED ACCORDING TO THREE SUBCUTANEOUS FAT THICKNESS GROUPS

	Subcutaneous fat thickness group[a]		
Palatability attribute	1	2	3
Number of observations	72	85	97
Juiciness[b]	4.94^{fg}	4.81^{g}	5.12^{f}
Myofibrillar tenderness[c]	5.01^{h}	5.39^{g}	5.91^{f}
Connective tissue amount[d]	6.18^{h}	6.56^{g}	6.82^{f}
Overall tenderness[c]	4.83^{h}	5.27^{g}	5.82^{f}
Flavor desirability[e]	4.91^{h}	5.44^{g}	5.80^{f}
Overall palatability[e]	4.50^{h}	5.05^{g}	5.59^{f}
Shear force, lb	15.66^{h}	11.62^{g}	9.53^{f}

[a]1 = 0.19 in. or less; 2 = 0.20 to 0.39 in.; 3 = 0.40 in. or greater.

[b]8 = extremely juicy; 1 = extremely dry.

[c]8 = extremely tender; 1 = extremely tough.

[d]8 = none; 1 = abundant.

[e]8 = extremely desirable; 1 = extremely undesirable.

[f,g,h]Means in the same row bearing a common superscript letter are not significantly (P>.05) different.

0.40 in. or greater, was at least equivalent to, and perhaps slightly more precise than, the use of quality grades (Choice, Good or Standard) for grouping the carcasses of the present population according to expected eating quality of their rib steaks; similar results are evident in Tables 3 and 7. That the two methods of grouping carcasses were similar in segmentation accuracy was not unexpected, since the simple correlation between marbling score and fat thickness was relatively high (r = .63). Steaks from carcasses with at least 0.40 in. of fat thickness were similar in palatability characteristics to steaks from Choice carcasses, steaks from carcasses with 0.20 to 0.39 in.of fat thickness were generally equivalent in palatability to steaks from Good grade carcasses and steaks from carcasses with 0.19 in. or less fat thickness were similar in palatability to steaks from Standard grade carcasses. While the 0.20 to 0.39 in. and the 0.40 in. or more fat thickness groups correctly identified larger percentages of "desirable" and "very desirable" steaks than did the Good and Choice grades, the Standard grade identified relatively more of the carcasses with "undesirable" steaks than did the group with 0.19 in. or less fat thickness.

It has been reported that once cattle have been fed a high-concentrate diet for a certain period of time, they produce steaks of highly acceptable palatability, regardless of their marbling amounts or quality grades (11). To determine the usefulness of carcass fat thickness for predicting palatability in a population of carcasses from fed cattle, data from the cattle fed 90 to 160 days were stratified according to fat thickness ranges (Table 8). Steaks from carcasses with at least 0.20 in. of fat were superior ($P<0.05$) to steaks from carcasses with less subcutaneous fat (0.19 in. or less) for all palatability attributes. Steaks from carcasses with less than 0.10 in. of external fat received the lowest ($P<0.05$) sensory panel ratings for myofibrillar tenderness and had the highest ($P<0.05$) shear force values. As fat thickness of carcasses from cattle fed 90 to 160 days increased from less than 0.10 in. up to 0.29 in., there were progressive increases in palatability of cooked beef; however, deposition of subcutaneous fat in quantities greater than 0.29 in. did not further improve cooked beef palatability. The data from this population of cattle, carcasses, and steaks support the theory that subcutaneous fat thickness could be used as an alternative to the present USDA quality grading system for predicting beef palatability.

TABLE 7. FREQUENCY PERCENTAGES OF STEAKS WITHIN EACH OF THREE LEVELS OF OVERALL TENDERNESS, FLAVOR DESIRABILITY AND OVERALL PALATABILITY STRATIFIED ACCORDING TO THREE SUBCUTANEOUS FAT THICKNESS GROUPS

	Subcutaneous fat thickness group[a]		
	1	2	3
Number of observations	72	85	97
Overall tenderness[b]			
"Very desirable"	23.6	33.0	48.5
"Desirable"	43.1	43.5	47.4
"Undesirable"	33.3	23.5	4.1
Flavor desirability[b]			
"Very desirable"	4.2	18.8	47.4
"Desirable"	66.6	74.1	51.6
"Undesirable"	29.2	7.1	1.0
Overall palatability[b]			
"Very desirable"	5.6	16.5	38.1
"Desirable"	50.0	61.2	51.6
"Undesirable"	44.4	22.3	10.3

[a]1 = 0.19 in. or less; 2 = 0.20 to 0.39 in.; 3 = 0.40 in. or greater.

[b]"Very desirable" = mean sensory panel ratings of 6.00 or higher; "Desirable" = mean sensory panel ratings of 4.50 to 5.99; "Undesirable" = mean sensory panel ratings lower than 4.50.

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TABLE 8. MEAN VALUES FOR PALATABILITY ATTRIBUTES OF STEAKS FROM STEERS FED A HIGH-CONCENTRATE DIET FOR 90, 100, 130 OR 160 DAYS STRATIFIED ACCORDING TO SUBCUTANEOUS FAT THICKNESS GROUP

	Subcutaneous fat thickness group[a]							
Palatability attribute	1	2	3	4	5	6	7	8
Number of observations	3	10	28	33	37	21	14	20
Juiciness[b]	5.00[f]	4.91[f]	4.90[f]	4.95[f]	5.06[f]	5.29[f]	5.31[f]	5.03[f]
Myofibrillar tenderness[c]	3.87[h]	5.02[g]	5.75[f]	5.66[f]	6.01[f]	5.98[f]	6.10[f]	5.78[f]
Connective tissue amount[d]	5.87[g]	6.25[g]	6.69[f]	6.66[f]	6.90[f]	6.82[f]	6.81[f]	6.75[f]
Overall tenderness[c]	3.77[g]	4.86[g]	5.60[f]	5.57[f]	5.97[f]	5.84[f]	5.99[f]	5.66[f]
Flavor desirability[e]	5.17[fg]	4.93[g]	5.53[f]	5.55[f]	5.80[f]	5.86[f]	5.81[f]	5.74[f]
Overall palatability[e]	3.77[g]	4.49[g]	5.26[f]	5.32[f]	5.63[f]	5.67[f]	5.75[f]	5.50[f]
Shear force, lb	17.24[i]	13.52[h]	10.69[g]	10.14[fg]	9.06[f]	9.33[fg]	9.19[fg]	10.10[fg]

[a]1 = 0.09 in. or less; 2 = 0.10 to 0.19 in.; 3 = 0.20 to 0.29 in.; 4 = 0.30 to 0.39 in.; 5 = 0.40 to 0.49 in.; 6 = 0.50 to 0.59 in.; 7 = 0.60 to 0.69 in.; 8 = 0.70 in. or greater.

[b]8 = extremely juicy; 1 = extremely dry.

[c]8 = extremely tender; 1 = extremely tough.

[d]8 = none; 1 = abundant.

[e]8 = extremely desirable; 1 = extremely undesirable.

[f,g,h,i]Means in the same row bearing a common superscript letter are not significantly (P>.05) different.

PR-3938

Breed and Heterosis Effects on Carcass Merit

J. F. Baker and C. R. Long

Summary

Carcass data from bulls of five breeds — Angus, Brahman, Hereford, Holstein and Jersey — and their crosses (reciprocals pooled) were analyzed for this study. There were 107 individually fed and 206 group fed bulls that ranged from 12 to 24 months of age at slaughter. Breed-type means and average heterosis estimates are reported for measures of: thoracic depth, round thickness, chuck thickness, carcass length, ribeye area, fat thickness, KPH fat (kidney, pelvic and heart fat), carcass weight, conformation score, marbling score, final grade and estimated percentage of boneless retail cuts. Among the straightbreds, the Holstein was larger in all the linear measurements and the Jersey smallest with exception of thoracic depth. The Holstein and Jersey were ranked last among the straightbreds for fat thickness and second and third for KPH fat. The Hereford and Angus ranked high for conformation score, marbling score and final grade; the Holstein and Jersey ranked low for these characters. The Brahman, Holstein and Angus ranked above the Jersey and Hereford for estimated percentage of retail cuts. The estimates of heterosis for the linear carcass measurements, ribeye area and weight were positive and indicated an advantage for the crossbreds. The heterosis estimates for the various fat measurements were mixed. The estimates for KPH fat and marbling indicated that the crossbreds were fatter but the estimate of heterosis for fat thickness over the 12th rib was negative. The heterosis estimates for the USDA factors were all small in magnitude and suggest little difference between straightbreds and crossbreds in this study for these factors. Results for this study support the contention that breedtypes should be compared in the context of a production system on the basis of total efficiency.

Introduction

Commercial cattle breeders seeking to improve efficiency and productivity should evaluate all phases of the beef production system. The necessity for carefully identifying the special contributions to total efficiency by the three components of the production system — the sire, the dam and the slaughter offspring — has been emphasized previously (1). Traits of major importance for one component may be unimportant or even antagonistic to the efficient contribution to the system of another component.

The Texas Agricultural Experiment Station Project H-1936 entitled "Evaluation of Hybrid Systems for Total Efficiency of Beef Production" was designed to quantify breed and heterosis effects upon and relationships among varying performance levels for characters which have large effects on total efficiency of beef production. This paper reports measures of carcass merit in bulls of five breeds and their crosses (reciprocals pooled). The term carcass merit is intended to include quality of product and quantity of edible portion.

Materials and Methods

The project was designed as a five breed diallel involving Angus, Brahman, Hereford, Holstein and Jersey; reciprocal crosses were pooled so there were 5 straightbred and 10 crossbred breedtypes. The number of bulls in each breedtype and management subclass are given in table 1.

At approximately 6 months of age, the bulls were assigned to either individually fed serially slaughtered or group fed management. Bulls in the individually fed regime were slaughtered at 12, 15, 18 or 24 months of age. Group fed bulls were slaughtered at ages throughout this range and classified according to age at slaughter with the same intervals as the individually fed. After bulls were slaughtered and the carcasses chilled for 24 hours, thoracic depth, round thickness, chuck thickness, carcass length, ribeye area, fat thickness, KPH fat (kidney, pelvic and heart fat), chilled carcass weight, conformation score, marbling score and final quality grade were recorded (2). Percentage boneless retail cuts was estimated using the equation $Y = 51.34 - 2.28$ (fat thickness, cm) $-$ .462 (percent KPH fat) + .144 (area ribeye muscle, square cm) $-$ .021 (warm carcass weight, kg) adapted from Murphey *et al.* (4). Table 2 contains the codes used for the USDA quality grades, maturity scores and marbling scores.

Results and Discussion

A statistical model with breedtype, management group and slaughter group within management was used to analyze the data. Breedtype was a significant source of variation for all the variables reported with the exception of maturity. Management and slaughter groups were significant sources of variation for the cooler characters but were nonsignificant for many of the USDA factors. Least squares means for straightbred and crossbred groups as well as average heterosis estimates are presented in tables 3 and 4.

Among the straightbreds, Holsteins were larger in all proportions (table 3). The straightbred Jersey ranked second for thoracic depth but was more similar to the British breeds than the larger Holstein. The Holstein and Jersey ranked lowest among the straightbreds for fat thickness and second and third for KPH fat. The dairy breeds, often noted for high percentage KPH fat, ranked lower than the Hereford, the fattest straightbred breedtype, for weight of KPH fat.

Among the crossbreds, the Angus × Hereford cross exhibited greater chuck and round thickness

TABLE 1. NUMBER OF BULLS IN EACH BREEDTYPE BY MANAGEMENT SUBCLASS

	Angus	Brahman	Hereford	Holstein	Jersey	
Angus	3/6	3	3	21	17	
Brahman	7	11/8	14	17	17	
Hereford	8	7	41/8	18	11	206 Group Fed
Holstein	8	6	7	20/7	8	
Jersey	6	8	7	7	2/7	
			107 Individually Fed			

[a]Group fed numbers are above and to the right of the marks on the diagonal and the individually fed are below and to the left.

TABLE 2. CODES FOR USDA QUALITY GRADES, MATURITY SCORES AND MARBLING SCORES

Quality grade		Maturity score		Marbling score	
Grade	Code	Score	Code	Score	Code
Utility –	7	E+	1	Devoid –	1
Utility°	8	E°	2	Devoid°	2
Utility +	9	E–	3	Devoid +	3
Commercial –	10	D+	4	Practically devoid –	4
Commercial°	11	D°	5	Practically devoid°	5
Commercial +	12	D–	6	Practically devoid +	6
Standard –	13	C+	7	Trace –	7
Standard°	14	C°	8	Trace°	8
Standard +	15	C–	9	Trace +	9
Good –	16	B+	10	Slight –	10
Good°	17	B°	11	Slight°	11
Good +	18	B–	12	Slight +	12
Choice –	19	A+	13	Small –	13
Choice°	20	A°	14	Small°	14
Choice +	21	A–	15	Small +	15

than the other breedtypes. The Holstein crossbreds generally ranked in the highest five for thoracic depth and carcass length. The Holstein × Jersey cross ranked first for the depth and length measurements. The Jersey crossbreds ranked low for ribeye area; this ranking was not unexpected since the least squares mean for Jersey was almost 3 square inches less than the other straightbreds. The Hereford crosses generally ranked high for ribeye area. No pattern was apparent for the crossbred rankings for the fat measurements or chilled carcass weight. The Jersey and Jersey crossbreds did have the lighter carcass weights, however.

Average heterosis estimates for the cooler measurements (table 3) were positive except for fat thickness. This indicates that the crossbreds were larger in the dimensions measured and were more muscular. The interesting comparison is between the two measures of fatness. The positive heterosis for KPH fat conflicts with the negative heterosis for fat thickness measured at the 12th rib. Generally other studies have reported positive heterosis for fat thickness however negative heterosis has also been reported (3). The negative heterosis for fat thickness in this study could be due in part to differences in location of fat deposition of the particular breedtypes involved. The heterosis values reported in this paper are average heterosis estimates from all ten crossbred breedtypes.

Table 4 contains the least squares means and average heterosis estimates for the USDA factors evaluated. Among the straightbreds, the traditional beef breeds, the Hereford and Angus, ranked high for conformation score, marbling score and final grade. The Brahman was intermediate and the Holstein and Jersey ranked fourth and fifth. The least-squares means for maturity score were all within the A maturity group. According to USDA standards any carcass within the A maturity group is designated only as "A maturity".

The straightbred Angus and Brahman ranked above the other three straightbreds for estimated percent cutability. The Jersey ranked low because it was small and had a large amount of KPH fat. The Hereford had a heavy carcass weight and ranked high for ribeye area but was the fattest of the straightbreds and consequently ranked lower for estimated percent cutability.

TABLE 3. BREEDTYPE LEAST-SQUARES MEANS AND AVERAGE HETEROSIS FOR COOLER MEASUREMENTS

Breedtype	Thoracic depth (in)	Round thickness (in)	Chuck thickness (in)	Carcass length (in)	Ribeye area (in)	Fat thickness (in)	KPH fat (lb)	Chilled carcass wt. (lb)
Angus (A)	15.7	9.6	6.4	47.9	11.9	.21	11.2	624
Brahman (B)	15.7	9.3	5.7	47.0	11.6	.15	9.7	575
Hereford (He)	15.5	9.4	6.9	47.2	12.3	.31	15.2	650
Holstein (Ho)	17.2	9.7	6.5	53.3	12.3	.13	14.1	714
Jersey (J)	15.9	7.5	5.2	47.3	9.2	.12	12.1	459
Straightbred mean	16.0	9.1	6.1	48.5	11.5	.19	12.6	604
AB	16.1	9.8	6.9	49.6	13.2	.24	15.7	672
AHe	15.6	10.0	7.4	48.1	13.2	.28	15.7	697
AHo	16.5	9.8	6.8	50.5	12.8	.14	12.1	675
AJ	15.8	8.9	6.3	47.6	11.4	.16	14.1	571
BHe	15.9	9.6	6.4	48.8	13.5	.17	11.5	644
BHo	16.4	9.5	6.5	51.4	12.8	.13	12.3	699
BJ	16.1	9.0	5.9	48.7	11.1	.13	11.7	582
HeHo	16.5	9.5	6.8	50.6	12.9	.18	14.6	712
HeJ	15.7	8.8	6.2	47.9	11.8	.16	13.4	564
HoJ	16.8	9.3	6.0	51.6	11.1	.11	12.6	631
Crossbred mean	16.1	9.4	6.5	49.5	12.4	.17	13.4	646
Overall mean	16.1	9.3	6.4	49.2	12.1	.17	13.0	631
Average heterosis								
Units	.2	.3	.4	.9	.9	−.02	.9	40
%	1.0	3.0	6.4	1.9	8.1	−8.5	7.0	6.6

[a]Due to round-off error, there may be an apparent discrepancy between the value for average heterosis in units and the difference between the crossbred and straightbred means as given in the table.

TABLE 4. BREEDTYPE LEAST-SQUARES MEANS AND AVERAGE HETEROSIS FOR U.S.D.A. FACTORS

Breedtype	Conformation	Maturity	Marbling	Final Grade	Estimated % Cutability
Angus (A)	21.3	13.5	9.0	15.4	54.03
Brahman (B)	19.3	14.0	6.9	14.2	54.28
Hereford (He)	21.2	13.8	9.4	15.9	53.20
Holstein (Ho)	17.7	13.5	5.8	12.6	53.50
Jersey (J)	15.8	13.5	5.6	13.1	53.39
Straightbred mean	19.1	13.7	7.3	14.2	53.68
AB	20.0	13.6	7.4	13.6	53.98
AHe	21.9	13.7	9.1	15.6	53.41
AHo	19.4	13.4	8.0	14.7	54.30
AJ	18.8	13.6	7.7	14.5	54.09
BHe	19.9	13.5	7.1	14.0	54.87
BHo	17.9	13.5	6.3	13.4	54.03
BJ	18.0	13.5	6.5	13.8	53.87
HeHo	19.9	13.3	7.6	14.3	53.76
HeJ	18.3	13.6	8.9	15.6	54.51
HoJ	16.2	13.1	7.1	14.1	53.43
Crossbred mean	19.0	13.5	7.6	14.4	54.02
Overall mean	19.0	13.5	7.5	14.3	53.91
Average heterosis, units	0	−.2	.2	.1	.34
%	0	−1.5	2.7	.7	.6

[a]Due to round-off error, there may be an apparent discrepancy between the value for average heterosis in units and the difference between the crossbred and straightbred means as given in the table.

The crossbred rankings for conformation and marbing scores and final grade were higher for the Angus and Hereford crosses. The Angus × Hereford cross specifically ranked first for conformation and marbling scores and final grade. The Hereford × Jersey cross also ranked high except for conformation score. The Holstein crosses were generally ranked lower for conformation, marbling and final grade.

Average heterosis estimates were all small in magnitude for the USDA factors. The difference between the straightbred mean and the crossbred mean was not greater than one unit for any USDA factor. This small difference indicates no actual advantage for the crossbred bulls in this study for the USDA factors.

Carcass merit of the slaughter offspring is one

criterion that is considered by producers whose objective is to improve the efficiency of the production system. Ranking of breedtypes for superior carcass merit is not a simple task. The Holstein would rank high for length, thickness and weight of carcass but the Holstein and dairy crosses would rank low for the USDA factors. The Angus, Hereford and the Angus-Hereford cross would rank high for the USDA fators but would also be fatter than the other breedtypes. Some of the breedtypes excel (with respect to these criteria) for one or several characters while ranking low in others, or a breedtype may be intermediate for most of the characters. Carcass merit is only one criterion of the system that is considered by commercial cattle breeders. Including sire and dam components complicates the task of evaluating breedtypes for production efficiency. The results of this study will be used in systems analysis research to provide comparisons and recommendations for specific production circumstances.

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PR-3939

Feedlot Performance and Carcass Characteristics of Hereford and Texas Longhorn × Hereford Steers

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Summary

Performance and carcass data from 80 Hereford and 80 Texas Longhorn × Hereford F_1 steers were compared in a growth trial. Hereford steers gained more rapidly ($P<.05$) up to 155 days after which the Texas Longhorn × Herefords gained slightly more weight per day. Conversion of feed dry matter to weight gain indicated that Herefords were more efficient than Texas Longhorn × Hereford steers, except during the last 12 days on feed. Herefords increased more in percentage units of 9-10-11 rib fat and therefore decreased more in lean and bone percentage during finishing than Texas Longhorn × Hereford steers. Muscle to bone ratio at terminal slaughter was greater for Texas Longhorn × Hereford steers (3.02:1) than for Herefords (2.77:1). Carcasses from Texas Longhorn × Hereford steers had less ($P<.05$) youthful lean scores, and higher marbling scores and USDA quality grades than Herefords. Texas Longhorn cross steers also deposited less ($P<.05$) external carcass fat, had lighter carcasses and lower (higher yield) USDA yield grades. Steaks from Texas Longhorn × Hereford carcasses were more desirable ($P<.05$) in flavor but the two breed types were nearly equal in all other palatability characteristics. These data indicate the Texas Longhorn × Hereford cross steers differed in some carcass and palatability traits and in rate and composition of growth from Herefords.

Introduction

Cattlemen must continuously strive to identify types of cattle that offer potential in contributing to the efficient production of beef. Numerous combinations of production environments and types of cattle allow for many successful production alternatives to evolve. To assist cattlemen in developing beef production systems, certain fundamental data must be available. While it may be assumed that the Texas Longhorn was the earliest type of cattle to evolve in Texas, almost no published data on breed characterizations are available.

Limited reports (1, 8, 9) on performance of Texas Longhorn and Texas Longhorn cross cattle are available. Some authors (4, 11, 14) have discussed Texas Longhorn origin but not until recently have producers expressed concern for data to assist in characterizing the breed. The histocompatibility complex of Texas Longhorns and other breeds of cattle has been under investigation to determine potential relationships to disease resistance (2).

Therefore a field trial was established to obtain data on rate and efficiency of growth plus carcass and palatability characteristics of Hereford and Texas Longhorn × Hereford cattle.

Procedure

Hereford and Texas Longhorn × Hereford first cross steers were obtained from the 1979 calf crop of the Mashed O Ranch, Council Grove, Kansas on March 5, 1980. Eighty representative Hereford steers were obtained from the 362 steers from Hereford cows that had produced two or more calves in the herd. The 80 Texas Longhorn × Hereford F_1 steers represented most of the male progeny from first calf heifers mated to Texas Longhorn bulls. The Texas Longhorn bulls were obtained from three different

herds. The Hereford genetic base was relatively uniform although limited in scope to represent a breed selection. This same limitation may apply to the 15 Texas Longhorn bulls that served as the sires of these crossbred steers. All calves were born from March through April 1979 and managed under similar ranch conditions prior to and after weaning in October. The entire group of 160 steers were shipped to the Swisher County Cattle Company feedlot of Tulia, Texas on March 5, 1980 where they were fed and managed in the established routine of that commercial feedlot until slaughtered.

Upon arrival at the feedlot, all steers were processed in a like manner including implantation with one Synovex-S implant and randomly assigned to one of two replicates (pens) per treatment. Each replicate of steers was weighed and visually scored according to U.S.D.A. Feeder Grade standards (12) for frame size and muscling score by a committee of three experienced evaluators. From March 5 until May 6 (60 days) the steers were fed starter and growing rations (table 1). Cattle were fed the same high energy ration (table 1) throughout the finishing portion of this study. Data on feed intake was recorded by replicates each day. Steer weights were obtained at three intervals during finishing by replicates and health records maintained throughout the experiment.

Four steers of each breed type were slaughtered on May 7 to serve as controls to obtain muscle-to-bone ratios. The 9-10-11th rib section was removed from the left side of each carcass following accepted procedures (5). The remaining 152 steers were to be fed to establish two endpoints at slaughter. Half of the steers from each replicate were slaughtered on October 8 and all remaining steers on October 20 to obtain carcass data.

Forty carcasses (20 from each treatment) were randomly selected and the 9-10-11th rib sections were removed at the last slaughter as previously outlined. Physical separation and chemical analysis for fat in the *longissimus dorsi* and lean portions allowed fat, bone, and muscle determinations for the 9-10-11th rib section and muscle-to-bone ratio calculations to be made. After the *longissimus dorsi* of each rib had been separated and weighed, two steakes (1.25 in. thick) from the 11th rib were removed, wrapped in polyethylene-coated freezer paper, frozen and stored at −4 F. These steaks were subsequently removed from the freezer, thawed at 34 F and broiled on a Farberware Open Hearth Broiler to an internal temperature of 160 F.

Samples of one cooked steak from each rib were evaluated by an eight-member trained sensory panel for juiciness, muscle tenderness, amount of detectable connective tissue, overall tenderness, flavor desirability and overall desirability using eight-point descriptive scales. Cores (.5 in diameter) were removed from the second steak (six to ten cores per steak) for shear force determination by use of a Warner-Bratzler shear machine.

Data were subjected to analysis of variance and Duncan's multiple range test to determine significance of differences between breed types for variables compared.

A sample of the cattle were blood typed in an attempt to characterize them according to breed structure. A total of 16 Hereford steers and 58 Texas Longhorn × Hereford steers and 10 of the 15 Texas Longhorn sires were blood typed.

Results and Discussion

Steers of both breed types were between 13 and 14 months of age and within 14 lb for average body weight (table 2) at initiation of the finishing trial. Steers slaughtered as controls (table 3) did not differ ($P>.05$) in muscle-to-bone ratio, percentage fat or lean in the 9-10-11 rib, although Hereford steers had more ($P<.05$) bone than Texas Longhorn × Herefords. These data indicate that body composition, weight, and age were relatively similar for both Hereford and Texas Longhorn cross steers when placed on feed.

Growth data (table 2) indicate that Herefords gained more rapidly ($P<.05$) up to 155 days after which the Texas Longhorn × Herefords gained slightly more per day. The declining rate of gain with advancing days on feed is consistent with a large body of published data for cattle of this description and management. In this study the slower-gaining cattle (Texas Longhorn × Hereford) exhibited a slower rate of decline with advancing time on-feed than Herefords. Feed consumption was similar for both breed types and declined drastically after 155 days, indicating that the cattle were not gaining rapidly at that time. Conversion of feed dry matter to liveweight gain favored the Hereford steers. Earlier researchers (1) compared representative purebred

TABLE 1. ANALYSIS OF RATIONS FED, PERCENT

Ration[a]	Days on each ration	Dry matter	Nutrient, dry matter basis				
			Crude protein	Acid detergent fiber	TDN	Ca	P
Starter	14	85.8	14.0	21.5	72.5	.90	.41
Grower	46	50.8	14.2	24.1	71.2	.71	.18
Finisher	172	77.7	12.9	11.6	80.5	.70	.29

[a]Numbers of samples represented for starter, grower and finisher rations were 1, 4 and 4, respectively.

TABLE 2. AVERAGE FEEDLOT PERFORMANCE OF STEERS DURING FINISHING PERIODS

Item	No. of Steers	Breed type: Hereford	Breed type: Texas Longhorn × Hereford
Live weight, lb.[a,b]			
Initial	80	685.9 ± 6.3	699.3 ± 1.6
After 80 days on feed**	76	938.4 ± 6.7	920.5 ± 4.0
After 155 days on feed*	76	1137.0 ± 13.8	1087.0 ± 3.5
After 172 days on feed**	38	1160.7 ± 21.6	1113.7 ± 2.4
Daily gain by periods, lb.			
From 0 to 80 days*	76	3.15 ± .00	2.76 ± .07
From 81 to 155 days*	76	2.64 ± .09	2.21 ± .01
From 156 to 172 days	38	1.39 ± .46	1.56 ± .34
Avg. feed dry matter consumption per day by periods, lb.			
From 0 to 80 days	76	26.5 ± 1.68	26.5 ± .43
From 81 to 155 days	76	25.6 ± .95	25.6 ± .34
From 56 to 172 days	38	17.6 ± .56	16.3 ± .63
Conversion of feed dry matter to live weight gain by periods, lb.			
From 0 to 80 days	76	8.4	9.6
From 81 to 155 days**	76	9.7	11.6
From 156 to 172 days	38	12.7	10.5
Cumulative feedlot cost per head, $			
From 0 to 80 days	76	179.71	181.28
From 0 to 155 days	76	303.21	300.11
From 0 to 172 days	38	322.50	318.05

*(P<.05)

**(P<.01)

[a]Calves maintained in feedlot 60 days prior to initiation of finishing period. Off-truck weights upon arrival at the feedlot were 509 and 528 lbs, respectively, for Hereford and Texas Longhorn × Hereford steers.

[b]All live weights represent unshrunk weights.

Hereford and Longhorn steers by attempting to develop them to the constant endpoint of Low Choice. Their data also indicated that Longhorns gained slower (P<.05) and required more feed per pound of gain than Herefords.

The 9-10-11 ribs of Hereford steers exhibited a greater increase in fat and a greater decrease in lean and bone (table 3) than Texas Longhorn × Hereford steers from control to terminal slaughter. Herefords had higher bone percentage (P<.05) at the control slaughter than Texas Longhorn crosses and higher fat percentage (P<.05) at the terminal slaughter. Muscle-to-bone ratios were more desirable for Texas Longhorn × Hereford steers at terminal slaughter. These data establish that the Hereford steers changed more in rib section composition than the Texas Longhorn

TABLE 3. MEAN VALUES FOR 9-10-11 RIB COMPOSITION AND MUSCLE-TO-BONE RATIO

Item	Initial slaughter (N = 8): Hereford	Initial slaughter (N = 8): Texas Longhorn × Hereford	Terminal slaughter (n = 40): Hereford	Terminal slaughter (n = 40): Texas Longhorn × Hereford	Percentage units change, initial vs. terminal: Hereford	Percentage units change, initial vs. terminal: Texas Longhorn × Hereford
Fat, %[a]	23.9	27.1	48.6[x]	45.3[y]	+24.7	+18.2
Lean, %[a]	58.2	56.9	37.7[x]	41.1[y]	−20.5	−15.8
Bone, %[a]	17.9[b]	16.0[c]	13.7	13.7	− 4.2	− 2.3
Muscle-to-bone ratio	3.26	3.55	2.75[x]	3.00[y]	−.51	−.55

[a]Taken as a percentage of 9-10-11 rib.

[b,c]Means with different superscripts differed (P<.05) for control slaughter, May 7.

[x,y]Means with different superscripts differed (P<.05) for terminal slaughter, October 20.

crosses during the finishing program. Carcasses resulting from the pure Hereford and pure Longhorn steers reported earlier (1) tend to support these observations since Longhorns resulted in a 1.94:1 muscle to fat ratio *vs.* 1.42:1 for Herefords. Data from the current study also (table 4) indicated that Texas Longhorn × Hereford steers were larger framed with near-equal muscling compared to Herefords.

Since carcass traits were similar ($P<.05$) for both the October 8 and 20 slaughter, their combined mean values are presented in table 5. These data suggest that Texas Longhorn × Hereford crossbred steers, when compared to Herefords of approximately the same chronological age (18 to 19 months at slaughter), had lower dressing percentages and carcasses that were more advanced in USDA lean maturity scores. Also, Texas Longhorn cross steers produced carcasses that were higher in marbling score, which resulted in differences ($P<.05$) in USDA quality grade between the two groups. Texas Longhorn cross steers also deposited less external fat as indicated by the adjusted fat thickness and as a result had a lower (higher yield) yield grade. Differences in ribeye area were small ($P>.05$), Hereford steers deposited less fat ($P<.05$) in the kidney, pelvic and heart areas than crossbreds. Hereford steers were heavier at the terminal slaughter and, as expected, produced heavier carcasses. These data are in general agreement with those of previous researchers (1).

Steaks from Texas Longhorn cross steers were more desirable in flavor but approximately equal in all other palatability characteristics (juiciness, muscle fiber tenderness, connective tissue amount, overall tenderness, overall palatability, and shear force value) compared to Herefords (table 6). Taste panel data indicated that all steaks were above average and very desirable compared to similar sensory evaluations.

The blood types of the pure Herefords were typical and highly representative of that breed. Texas Longhorns were also representative of the Texas Longhorn breed. However, one steer possessed a blood type which had not been observed in this breed and was classified as non-typical. It was confirmed by visual appraisal that one animal in the group definitely originated from breeding other than Texas Longhorn.

TABLE 4. INITIAL FRAME SIZE AND MUSCLING SCORE OF STEERS

Item	No. of steers	Breed type: Hereford	Breed type: Texas Longhorn × Hereford
Frame size[a]	80	1.96	4.41
Standard deviation		.88	1.30
Muscling score[a]	80	6.89	6.00
Standard deviation		.81	.71

[a]USDA (12). Standard; coded: frame size, small = 1, 2, 3; medium = 4, 5, 6; large = 7, 8, 9 and muscling score, light = 1, 2, 3; moderate = 4, 5, 6; heavy = 7, 8, 9.

TABLE 5. MEANS WITH STANDARD DEVIATIONS FOR CARCASS TRAITS

Item	Breed type: Hereford (n=74)	Breed type: Texas Longhorn × Hereford (n=76)
Warm carcass weight, lb.*	750.6 ± 54.8	706.6 ± 48.9
Dressing percentage	65.3	64.2
Lean maturity[a]*	$A^{52} \pm 18.5$	$A^{59} \pm 24.8$
Marbling score[a]*	$Sl^{96} \pm 54.5$	$Sm^{54} \pm 85.8$
USDA quality grade*	Good + ±34.3	Choice− ±47.5
Fat thickness at 12th rib, in.*	0.83 ± .19	0.49 ± .15
Adjusted fat thickness, in.*	0.94 ± .20	0.57 ± .16
Kidney, pelvis and heart fat, %*	1.90 ± .41	2.23 ± .33
Ribeye area, in.^{2}	12.3 ± 1.05	12.0 ± 1.00
USDA yield grade[a]	4.14 ± .68	3.20 ± .53

[a]USDA (13) scores: Lean maturity: A^{00} = approximately 9 months, A^{100} = approximately 30 months. Marbling: Sl = slight, Sm = small. Slight = all of U.S. Good grade, Small = lower third of U.S. Choice grade. Yield grade on a scale from 1 to 5.

*($P<.05$).

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TABLE 6. MEANS WITH STANDARD DEVIATIONS FOR CARCASS PALATABILITY CHARACTERISTICS

Item	Breed type: Hereford (n=20)	Breed type: Texas Longhorn × Hereford (n=20)
Juiciness[a]	5.5 ± .60	5.6 ± .61
Muscle fiber tenderness[b]	6.7 ± .51	6.7 ± .84
Connective tissue amount[c]	7.7 ± .22	7.7 ± .50
Overall tenderness[b]	6.8 ± .47	6.0 ± .77
Flavor desirability[d]*	6.2 ± .44	6.7 ± .37
Overall desirability[d]	6.3 ± .46	6.6 ± .70
Shear force value, lb.	6.2 ± 1.29	6.0 ± 1.41

[a]Based on 8 point scale: 8 = extremely juicy, 1 = extremely dry.

[b]Based on 8 point scale: 8 = extremely tender, 1 = extremely tough.

[c]Based on 8 point scale: 8 = none, 1 = abundant.

[d]Based on 8 point scale: 8 = extremely desirable, 1 = extremely undesirable.

*($P<.05$).

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Performance, Carcass and Palatability Characteristics Of Banteng Crossbred Cattle

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Summary

Birth and weaning weights of Banteng crossbred calves were approximately 13 and 15 percent less, respectively, than the birth and weaning weights of purebred Charolais calves. Domestic control steers (crossbreds predominately of Charolais breeding) gained 0.41 pounds more per day over a 173 day feedlot period than did the Banteng crossbreds. The carcasses of the Banteng crossbreds had less subcutaneous fat, but had slightly more kidney, pelvic and heart fat. The Banteng crossbred carcasses also had lower numerical USDA yield grades, indicating that they would have a higher percentage of boneless, closely trimmed retail cuts from the round, loin, rib and chuck than would the domestic controls. The mean USDA quality grade for the Banteng crossbreds and domestic controls was average and high Good, respectively. Although the palatability characteristics for meat from the Banteng crossbreds were slightly lower than the palatability characteristics of the domestic controls, the values in general were very acceptable.

Introduction

This communication is the first report of data concerning *characteristics of Banteng crossbred cattle* in the United States. The Banteng (*Bos Bibos Banteng*) is indigenous to Southeast Asia and is still found in the wild state in the more remote portions of Java (3). While most Banteng cattle in the United States are located in zoos, on occasions a zoo may sell surplus animals to individuals. The Banteng is interfertile with domestic cattle and although the F_1 males are sterile, F_1 females are fertile.

This paper reports gestational, preweaning, postweaning and certain carcass and meat quality characteristics of first cross Banteng cattle along with similar data from contemporary domestic cattle.

Materials and Methods

Experimental Animals

The Banteng crossbreds and straightbred Charolais were bred and raised on the Camp Cooley ranch near Franklin in East Central Texas. The control steers were purchased by the ranch as weanlings. The dams of the calves were two and three-year old Charbray cows (Brahman bulls × Charolais cows) and two-year old purebred Charolais cows. The crossbred calves were sired both naturally and artifically by two Banteng bulls obtained from the Brookfield Zoo near Chicago, Illinois. Of the two bulls, Buddy and Junior, Buddy sired the majority of the calves. At five years of age, Buddy weighed 1400 lbs. Junior had an estimated weight of 1100 lbs. Birth and weaning weights of the Banteng crossbreds were compared with the birth and weaning weights from the ranch's purebred Charolais herd.

The feedlot animals consisted of eight Banteng crossbreds (five steers and three bulls) and eight domestic steers (controls). The domestic controls were large or medium frame No. 2 feeders. Collectively, they were a mixture of Charolais, Angus, Hereford and Brahman breeding with each steer having Charolais inheritance plus inheritance of one or more of the other three breeds mentioned. The Banteng crosses were very uniform in size and type and were medium frame No. 1 or 2 feeders. The animals were fed until the Banteng group was judged to have attained a USDA slaughter grade of high Good. The rations fed were commercially produced by the Ralston Purina Company. For the first 30 days of the feedlot period the animals were fed Cattle Grower, having a protein content not less than 12 percent and not more than 18 percent crude fiber. After the first 30 days, Purina Cattle Finisher was fed. That ration had a protein level of not less than 11.5 percent and not more than 9.0 percent crude fiber. Feed was available free choice and was weighed in and out of the troughs every 24 hours so that group consumption comparisons could be made. The feedlot period extended for 173 days.

Results and Discussion

Gestation lengths, birth weights and weaning weights (tables 1-3)

The length of gestation of the Banteng crossbred calves was similar to the parental breeds and ranged from a low of 281 days for the heifers born in 1977 to 290 days for the heifers born in 1978. Gestation lengths of purebred Banteng, Charolais and Brahman Cattle have been reported to be 287, 289 and 293 days, respectively (4,5,2).

Banteng crossbred calves were lighter at birth than purebred Charolais calves. Contemporary birth weights were not available for purebred Banteng calves in this study, but birth weights of purebred calves in Australia averaged only 37 lbs. as compared with 66 lbs. for Brahman-Shorthorn crossbred calves (1). Since purebred Banteng cows have mature weights of no more than 70 percent of those of Charbray and Charolais cows, this suggests that maternal effects are important to these differences in birth weights.

The 205 day adjusted weaning weights of the purebred Charolais calves were 13 and 18 percent greater than for Banteng crossbred calves out of Charbray and Charolais cows, respectively. Sire effects were an important cause of these differences since the dams of both the purebred Charolais calves and of the Banteng crossbred calves were similarly bred. The average age at which the calves were weaned varied widely from one year to the next with no attempt to wean groups of calves near their 205th day of age. As a result, 205 day adjusted weaning weights may not accurately predict what the actual weaning weight would have been for calves that were more or less than 30 days from their 205th day of age at the time of weaning.

TABLE 3. AVERAGE BIRTH AND WEANING WEIGHTS OF PUREBRED CHAROLAIS CALVES BORN IN 1977

Trait	Males	No.	Females	No.
Birth weight, lbs.	81.8 (2.3)[1]	33	71.8 (2.1)	32
Actual weaning weight, lbs.	506.2 (12.9)	33	484.5 (14.1)	32
Adj. weaning weight (205 days), lbs.	446.1 (7.9)	33	415.6 (9.0)	32
Age at weaning (days)	251.5 (5.0)	33	253.6 (5.5)	32

[1]Standard error of the mean.

TABLE 1. AVERAGE GESTATION LENGTH, BIRTH AND WEANING WEIGHTS OF CALVES PRODUCED BY ½ CHAROLAIS, ½ BRAHMAN COWS AND SIRED BY BANTENG BULLS

	1977				1978			
Trait	Males	No.	Females	No.	Males	No.	Females	No.
Gestation, days	284.4 (2.4)[1]	12	281.0 (1.6)	9	288.4 (1.9)	18	289.6 (1.9)	25
Birth weight, lbs.	65.9 (1.2)	13	66.5 (1.1)	11	70.0 (2.1)	27	61.2 (1.7)	29
Actual weaning weight, lbs.	402.3 (15.4)	13	382.3 (11.0)	11	335.6 (12.4)	27	302.6 (11.4)	29
Adj. weaning weight (205 days), lbs.	377.8 (11.8)	13	367.9 (10.6)	11	404.2 (9.6)	27	359.4 (7.9)	29
Age at weaning, days	221.8 (1.6)	13	218.6 (11.2)	13	164.3 (4.4)	27	165.3 (5.2)	29

[1]Standard error of the mean.

TABLE 2. AVERAGE GESTATION LENGTH, BIRTH AND WEANING WEIGHTS OF CALVES PRODUCED BY CHAROLAIS COWS AND SIRED BY BANTENG BULLS

	1977				1978			
Trait	Males	No.	Females	No.	Males	No.	Females	No.
Gestation, days	----		----		286.2 (3.9)[1]	12	287.0	2
Birth weight, lbs.	60.0	4	57.4	8	77.4 (2.1)	14	58.2	4
Actual weaning weight, lbs.	427.5	4	357.0	8	380.4 (15.1)	14	308.8	4
Adj. weaning weight (205 days), lbs.	382.4	4	350.9	8	362.2 (22.4)	14	334.5	4
Age at weaning, days	252.8	4	245.6	8	245.8 (19.0)	14	243.8	4

[1]Standard error of the mean.

Feedlot Performance (table 4)

The domestic steers gained 0.40 lbs. more per day and consumed 1.04 lbs. less feed per pound of gain than did the Banteng crossbreds. The feedlot period extended through the winter of 1978-79 which was unusually wet and cold for East Central Texas. Banteng cattle may undergo more stress during cold and wet weather than domestic cattle and this, along with their very nervous disposition likely contributed to their comparatively poor performance.

Carcass and Meat Quality Characteristics (tables 5-7)

Presented in tables 5 and 6 are carcass characteristics of first cross Banteng crossbred cattle and domestic crossbred controls. Banteng crossbreds had lighter weights (slaughter, hot carcass and chilled carcass) than the domestic controls; however, the dressing percentages were virtually the same for both groups (table 5). Even though the Banteng crossbreds had lighter carcass weights than the domestic controls, the ribeye area for both groups was very similar (table 6). Banteng crossbred cattle produced carcasses that had less subcutaneous fat (both actual and adjusted), had slightly more kidney, pelvic and heart fat, and had a lower numerical USDA yield grade (higher estimated percentage of boneless closely trimmed retail cuts from the round, loin, rib and chuck) than the domestic controls. Although both groups of cattle had virtually the same overall maturities, the domestic crossbreds had a higher average USDA quality grade than the Banteng crossbreds (high Good vs. average Good).

Meat palatability characteristics of Banteng crossbreds and domestic crossbreds are reported in table 7. The differences were small between the two groups for palatability characteristics and, although the palatability characteristics for meat from the Banteng crossbreds were slightly lower than for the domestic controls, the values were very acceptable.

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TABLE 5. CARCASS CHARACTERISTICS OF CROSSBRED BANTENG AND DOMESTIC CATTLE CONTROLS

Trait[1]	Banteng crossbreds	Domestic controls
Slaughter weight, lbs.	969.4	1070.0
	(22.3)[2]	(13.5)
Hot carcass weight, lbs.	654.5	713.6
	(15.6)	(14.3)
Chilled carcass weight, lbs.	620.0	684.2
	(15.0)	(12.6)
Dressing percentage	64.0	63.9
	(0.2)	(0.3)

[1]All values are expressed as an average of 8 observations.
[2]Standard error of the mean.

TABLE 6. COMPARISON OF CARCASS CHARACTERISTICS OF CROSSBRED BANTENG CATTLE WITH DOMESTIC CROSSBREDS

Trait[1]	Banteng crossbreds	Domestic crossbreds
Actual fat thickness, 12th rib, in.	0.19	0.27
	(0.03)[2]	(0.05)
Adjusted fat thickness, 12th rib, in.	0.19	0.33
	(0.03)	(0.04)
Ribeye area, sq. in.	12.88	13.16
	(0.41)	(0.06)
Kidney, pelvic, heart fat, %	2.94	2.38
	(0.27)	(0.18)
USDA yield grade	1.94	2.32
	(0.18)	(0.16)
Skeletal maturity[3]	^{A}57.50	^{A}63.75
	(3.66)	(3.75)
Lean maturity[3]	^{A}55.00	^{A}46.25
	(7.01)	(4.98)
Overall maturity[3]	^{A}55.00	^{A}55.00
	(4.23)	(4.23)
USDA quality grade[4]	8.12	8.60
	(0.30)	(0.38)

[1]All values are expressed as an average of 8 observations.
[2]Standard error of the mean.
[3]A^{00} = approximately 9 months chronological age; A^{100} = approximately 30 months chronological age
[4]9 = High Good, 8 = Avg. Good, 7 = Low Good

TABLE 4. COMPARISON OF FEEDLOT PERFORMANCE OF CROSSBRED BANTENG CATTLE WITH DOMESTIC CROSSBRED CONTROLS

Item	No. of animals	Avg. wt. on feed, lbs.	Days on feed	Avg. final feedlot wt., lbs.	Avg. daily gain, lbs.	lbs. feed/ lb. of gain
Banteng crossbreds[1]	8	610.0	173	969.4	2.1	10.4
Domestic crossbreds[2]	8	639.4	173	1070.0	2.5	9.3

[1]5 steers and 3 bulls (Banteng × Charolais and Charbray).
[2]8 steers predominately of Charolais breeding.

TABLE 7. MEAT PALATABILITY CHARACTERISTICS OF CROSSBRED BANTENG CATTLE AND DOMESTIC CROSSBRED CONTROLS

Trait[1]	Banteng crossbreds	Domestic crossbreds
Juiciness[3]	4.54	4.74
	(0.28)[2]	(0.32)
Connective tissue amount[4]	6.29	6.85
	(0.19)	(0.12)
Myofibrillar tenderness[5]	5.34	5.81
	(0.20)	(0.25)
Overall tenderness[5]	5.26	5.96
	(0.26)	(0.23)
Flavor desirability[6]	5.06	5.95
	(0.34)	(0.22)
Overall desirability[6]	5.08	5.60
	(0.19)	(0.19)
Shear force value, lbs.[7]	12.84	11.09
	(1.65)	(0.58)

[1]All values are expressed as an average of 8 observations.
[2]Standard error of the mean.
[3]8 = extremely juicy; 1 = extremely dry.
[4]8 = none; 1 = abundant.
[5]8 = extremely tender; 1 = extremely tough.
[6]8 = extremely desirable; 1 = extremely undesirable.
[7]Warner - Bratzler shear force values of ½ in. cores of meat.

PR-3941

Diurnal Variation in Weight and Rates of Shrink in Range Cows and Calves

R. K. HEITSCHMIDT AND A. B. JOHNSON

Summary

Cow-calf pairs were weighed on successive mornings to determine the effects of time of day on weight flux. While early morning weights of mature Hereford/Angus crossbred cows were approximately 2.5 percent less than late morning weights in both spring and summer, they did not differ significantly. Linear regression analyses indicated that drylot shrink of cows was primarily a function of length of time held in confinement. Rate of weight loss was approximately 1 percent every 3 hours after an initial 3 hour loss of 3.5 percent. Secondary factors were physiological status of cow (dry or wet), relative humidity (%), season (spring or summer) and initial cow weight. Shrink rates were slightly greater for wet cows, low relative humidity, summer, and lighter weight cows. Rate of shrink of calves was primarily related to calves weighing less than 117 lbs. not gaining weight and calves weighing more than 117 lbs. losing weight.

Introduction

Liveweight of livestock is used to evaluate the effect of experimental treatments on performance and to establish sale value for the producer. Weight differences reflect treatment or different production effects and weighing conditions.

The first objective of this study was to quantify differences in cow and calf weights as a function of time of day when weighed. The second objective was to examine the rate of drylot shrink of both cows and suckling calves as a function of length of shrink, environmental conditions, initial weight, and time of day when the animals were gathered and penned. This objective was established to evaluate the feasibility of gathering herds and then weighing after a predetermined period of shrink to standardize weights.

Methods

The study was conducted during the spring and summer of 1979 at the Texas Experimental Ranch. Two of the three herds in a four pasture deferred rotation system were selected for study. Each herd consisted of 24 Hereford/Angus crossbred cows of similar size and age. Ten of the 48 cows did not have a calf or had lost their calf prior to the study. Average date of calving for the 38 calves was mid-December. Both herds were lcoated in pastures approximately ¾ mile from the weighing facilities.

The first experiment was designed to examine the differences in cow and calf weights as a function of time of morning when the animals were gathered and weighed. The second experiment was designed to quantify the rate of weight loss during drylot shrink. Both experiments consisted of replicated spring and summer trials run one week apart. Weighing of an entire herd generally required approximately 30 minutes. Although time to gather a herd within a pasture varied depending upon herd location, gathering and trailing the herd to the working pens averaged approximately one hour. Ambient temperature (°C) and relative humidity (%) were recorded at time of each weighing.

Standard analysis of variance procedures were used to analyze the data from Experiment 1. The replicated 2×3 factorial designed model considered time of day, season of year, and herds as factors. Data from Experiment 2 were analyzed utilizing least squares stepwise linear regression procedures. A series of analyses were run with percentage shrink as the dependent variable. Independent quantitative variables included individual preshrunk weights, length of shrink, time-weighted averages for temperature, relative humidity and temperature/relative humidity ratios. Also incorporated into the model were physiological status of cow, season of trial, and initial time of day that the shrink began. Age of calf also was included as an independent variable in the calf weight analyses. The regression procedures add-

ed independent variables if they met the P = 0.50 level of significance for the partial F-value.

Results and Discussion

The analysis of variance indicated that lactating cows with calves (wet cows) gained a significant ($P<0.01$) amount of weight during the morning. This weight increase was assumed to be the result of increased rumen fill from grazing. Early morning weights averaged 1005 pounds while late morning weights averaged 1030 pounds. The analyses also indicated that the cows weighed significantly ($P<0.01$) more in the summer (1047 pounds) than in the spring (988 pounds).

Although the weight gain of dry cows from early to late morning was statistically non-significant, trends were similar to those established for wet cows but of reduced magnitude. Averaged across all trials, dry cow weights increased 13 pounds during the morning. The difference in weight flux between physiological status of cows likely reflected rumen fill and milk secretion.

Analyses of the calf weights indicated no significant ($P>0.05$) differences between early and late morning weights or between herds. While not significantly different, gains during the morning averaged 0.6 percent in May and 0.9 percent in July. This 0.3 percent average increase indicated that as the calves grew, diurnal variation in liveweights was becoming more pronounced.

Time in drylot (X_1) was the best single variable for predicting percent shrink of cows, (Table 1). The rate of shrink averaged approximately 1 percent every 3 hours after an initial 3 hour shrink of approximately 3.5 percent.

The second variable included was physiological status (dry or wet) (X_2). Wet cows lost 1.85 percent more weight than dry cows, regardless of time period. Predicted shrinks for dry cows were 5.2 percent and 9.4 percent as contrasted to predicted shrink for the wet cows of 7.0 percent and 11.2 percent for 12 and 24 hours, respectively.

For the third variable relative humidity (X_3) the -0.04 coefficient indicated that rate of shrink was reduced slightly as relative humidity increased. Selection of relative humidity over temperature was not initially expected. However, because of the close relationship between relative humidity and temperature during the trials ($r = -0.85$, $P<0.01$) temperature apparently became relatively unimportant once relative humidity was included.

For the fourth variable selected (season of year (X_4)) the -1.79 coefficient indicated that rate of shrink was less during the spring than summer.

The final variable selected was the initial preshrunk weight of the cow (X_5).

Variables not selected were ambient air temperature, the relative humidity/temperature index and the time of day that the trial began.

Rate of shrink (y) of the suckling calves was primarily a function of three variables: initial weight of calf (X_1); time in drylot (X_2); and time of day (X_3) the trial began (Table 2). The -1.60 intercept coefficient, suggested that no shrink was predicted until calves weighed approximately 117 pounds. The $+0.03$ coefficient for preshrink weight (X_1) suggested rate of shrink would increase slightly as initial weight of calf increased.

Time in drylot (X_2) was selected as the second best variable for predicting shrink of calves (Table 2). The $+0.10$ coefficient suggested a slightly greater shrink occurred as time in drylot was extended. The final variable selected was time of day when the shrink began (X_3). The -2.45 coefficient indicated rates of shrink declined during nights in contrast to daytime shrinks. This was most likely related to the lower temperatures and higher relative humidities experienced during nights relative to days.

These data suggest that if at all possible, cow weights should be collected at a similar time of day under similar environmental conditions. Also, a period of drylot shrink prior to weighing did not standardize range cow weights unless length of shrink and environmental conditions during the shrink were similar.

These data indicate that the magnitude of diurnal weight fluctuation and rate of drylot shrink of suckling calves is a function of weight with the lighter the calf the less diurnal weight fluctuation and rate of drylot shrink. But since calves at weaning often weigh 660 pounds, every precaution should be taken to obtain accurate weights, especially since 22 pounds differences in calf weaning weights has sufficient economic justification.

TABLE 1. STEPWISE LINEAR REGRESSION COEFFICIENTS SELECTED TO PREDICT WEIGHT LOSS OF RANGE COWS IN A DRYLOT

Regression Coefficients	R^2
$y = 2.45 + 0.35X_1$	0.60
$y = 0.98 + 0.34X_1 + 1.85X_2$	0.67
$y = 3.04 + 0.38X_1 + 1.82X_2 - 0.40X_3$	0.72
$y = 5.86 + 0.39X_1 + 1.80X_2 - 0.06X_3 - 1.79X_4$	0.79
$y - 9.11 + 0.40X_1 + 1.53X_2 - 0.60X_3 - 1.45X_4 - 0.10X_5$	0.80

Where y = shrink (%); X_1 = time in drylot (hours); X_2 = status of cow (0 = dry, 1 = wet); X_3 = relative humidity (%); X_4 = season of year (0 = spring, 1 = summer); and X_5 = initial weight of cow (kg). All associated R^2 values were significant at $P < 0.01$ (d.f. = 503).

TABLE 2. STEPWISE LINEAR REGRESSION COEFFICIENTS SELECTED TO PREDICT WEIGHT LOSS OF DRYLOTTED SUCKLING CALVES

Regression Coefficients	R^2
$y = -1.60 + 0.03\ X_1$	0.28
$y = -3.05 + 0.03\ X_1 + 0.10\ X_2$	0.35
$y = -4.14 + 0.03\ X_1 + 0.26\ X_2 - 2.45\ X_3$	0.41

Where y = shrink (%); X = initial weight of calf (kg); X_2 = time in drylot (hours); and X_3 = time of day trial was begun (0 = morning, 1 = afternoon). All associated R^2 values were significant at $P < 0.01$ (d.f. = 400).

Infectious, Nutrition and Toxic Diseases

PR-3942

Acute Pulmonary Emphysema and Edema in Ruminants

B. B. BOREN, G. T. SCHELLING AND W. C. ELLIS

Acute bovine pulmonary emphysema and edema (ABPE) is the most common respiratory distress syndrome which affects pastured beef cattle. ABPE is most likely to occur when cattle are subjected to a sudden change to fast-growing, lush forage, and in Texas ABPE is most prevalent in cattle grazing coastal bermuda grass in areas receiving more than 25 inches of rainfall per year.

Although the general areas in which ABPE is most likely to occur can be targeted, the sporatic nature of the syndrome makes experimentation difficult under natural conditions. However, ABPE can be induced experimentally by intraruminal administration of L-tryptophan (TRP) or its metabolites, indoleacetic acid (IAA) and 3-methylindole (3MI). Intravaneous doses of 3MI also induce ABPE whereas similar treatments of TRP and IAA do not. Due to this, 3MI is thought to be the metabolite which is absorbed into the blood and precipitates the formation of the lung lesions common to ABPE.

Four trials in an ongoing series of experiments of ABPE have been conducted. In trial 1, two wether goats were dosed with 0.3 gm 3MI/kg body weight (BW) via rumen cannula. In trials 2 and 3, four goats fed a grain and ground hay diet were dosed with 0.38 or 1.05 (trial 2); 2.1 or 4.2 (trial 3) gm TRP/kg BW. In trial 4, four Hereford steers were dosed intraruminally with TRP at .45 gm/kg BW. Two of the steers were fed a grain and cottonseed hull diet containing 50 ppm monensin and two received the diet without monensin.

Blood and rumen fluid samples were taken at regular intervals during the trials. The two goats in trial 1 showed slight symptoms at 4 and 18 hours post dose and died 7 and 27 hours after dosing. In trial 2, goats given the 1.05 TRP level were off feed by 24 hours post dose, however no symptoms of ABPE were observed in any of the animals. All goats in trial 3 went off feed and one animal on the 4.2 TRP level exhibited respiratory distress after 24 hours, but was completely recovered 12 hours later. None of the steers in trial 4 exhibited any respiratory distress and no gross lesions were found on the lungs at slaughter 120 hours post dose. However, histological examination of the lungs revealed lesions consistent with ABPE in all four steers. The two animals which received no monensin exhibited diffuse lesions consistent with ABPE whereas those given monensin had a few scattered lesions suggestive of only a very mild form of ABPE.

The results of these trials indicate 3MI can induce ABPE in goats whereas TRP administered at levels twelve times those found to cause ABPE in cattle had little effect. This may be due to a species difference in intraruminal TRP metabolism or the result of a change in TRP metabolism caused by a dietary factor. The apparent inhibition of the metabolism of TRP to 3MI in those animals in trial 2, 3 and 4 may be due to the type of fermentation common to high grain diets and accentuated by monensin.

PR-3943

A Toxin Associated with *Pasteurella Hemolytica*

A. B. RICHARDS AND H. W. RENSHAW

Bovine respiratory tract disease complex, more commonly known as Shipping Fever, and a major causative bacterial agent *Pasteurella hemolytica*, continue to be among the most significant problems facing the cattle industry. Although tremendous efforts have been directed toward producing efficacious treatments to protect cattle from this disease, the effectiveness of many of these preventative techniques remains questionable.

Recent data produced in this and other laboratories suggest that *P. hemolytica* excretes a toxin. Researchers have shown that when *P. hemolytica* is incubated with cattle white blood cells (leukocytes) the cattle cells are killed. This method however is fairly crude and requires a high, and most likely nonphysiologic, ratio of bacteria to leukocytes. In addition, bovine alveolar macrophages, cells located in

the lungs and generally considered the most important cells in the initial defense of the host against bacterial infection in the lungs, are also susceptible to the toxin associated with the organisms.

Our laboratory has successfully developed a method to examine aspects of the activity of bovine leukocytes and alveolar macrophages at a molecular level. We have demonstrated with our test system that at even lower concentrations of bacteria than used in other systems, metabolic processes of leukocytes and alveolar macrophages associated with anti-infectious mechanisms are totally halted.

Further tests using immune serum have shown that, while high antibody levels against *P. hemolytica* increase the interaction between bacteria and the host's leukocytes, the toxic factor continues to exert harmful effects. This information suggests that even at low concentrations, *P. hemolytica* has the potential of inactivating the host's cells responsible for normal lung defense, even in the presence of specific antibody induced either by natural exposure or vaccination.

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PR-3944

Influence of Temperature and Humidity on the Development of Cattle Fever Ticks

P. D. Teel and S. C. Fleetwood

Cattle fever ticks (*Boophilus annulatus* and *B. microplus*) fed on stanchioned cattle were studied under an array of temperatures and relative humidities (RH) in laboratory incubators at the Cattle Fever Tick Quarantine Laboratory, Falcon Heights, Texas. Tick egg production, egg hatch and larval mortality were measured as criteria for evaluation. The thermal maximum for embryo development in both tick species was indicated near 37°C and a minimum near 15°C. Oviposition was observed for both species at 10°C without subsequent hatch.

The drying power of the atmospheres created by increasing temperature and decreasing humidity was shown to have a detrimental effect on egg production, hatch and larval longevity. Conditions of 27°C and 75 percent RH or higher produced the greatest compliments of eggs and hatch whereas decreased humidities of 60 percent RH and 50 percent RH produced significantly less eggs ($P<.05$), and subsequent egg hatch ($P<.05$). Conditions of 37°C, 90 percent RH produced 2.8 and 4.4 percent hatch; 37°C, 75 percent RH produced 0.3 and 0.1 percent hatch, respectively for *B. annulatus* and *B. microplus*. Humidities below 75 percent at 37°C produced no hatch. Larval mortality was greater at 37°C than 27°C for each humidity tested. These data indicate that cattle fever ticks may only survive long periods in the field under a narrow range of temperature-RH conditions. A 2-year study is underway to evalute the micro-, meso-, and macro-climates of nine dissimilar rangeland habitats on the Rio Grande plain. Data from this study will enable a refined evaluation of the off-host phase of the tick life cycle under quarantine in laboratory incubators. In the absence of a realistic means of surveying for tick larvae in the field, results will assist in the identification of habitats that support the off-host phase of the life cycle and in the estimation of population dynamics. Tick elimination procedures imposed by quarantine requires either pasture vacation to starve tick larvae awaiting a host or a program of systematically dipping cattle. Knowing the type of microhabitats that support cattle fever ticks and the longevity of tick populations in these habitats would assist regulatory agencies in efficient use of current mandatory procedures and possibly suggest new or improved methods to augment the current program.

Feedstuff-Forage Utilization

PR-3945

Mastication of Forage Effects Upon Digestion Characteristics

M. MAHLOOJI, W. C. ELLIS AND K. R. POND

Both physical and chemical processes are involved in the digestion of forages and these are often interrelated. The structure of plant tissue is such that many digestible components are protected by indigestible structures such as the epidermis and cuticle of plant tissue. Mastication or other physical processes of digestion are required to break this barrier. Additional barriers are found within the structure of the plant, such as the vascular bundles and other tissues. Mastication can disrupt these subtissue barriers and thereby expose a greater proportion of the potentially digestible constituents to the chemical action required for their final digestion. Thus, physical degradation by mastication would expectedly have positive effects upon digestibility.

A reduction in particle size is also required for particles to pass from the rumen to the lower tract. Thus, physical reduction in particle size may have a negative effect upon digestibility by reducing the time the fibrous particle resides at the site (rumen) where it is capable of being digested.

The manner in which different forages are fragmented by mastication is being studied to relate such fragmentation to the rate and extent of chemical digestion of the fiber. This is done by allowing an animal to graze or otherwise consume forage, and then collecting samples of the masticated forage by esophageal cannulae.

Samples are freeze dried and separated into various sizes. The different size particles are assayed to determine three characteristics of chemical digestion: (1) the proportion of the total fiber which is capable of being digested if residence time does not limit digestion (*i.e.* potentially digestible fiber), (2) the rate of hydrolysis of the potentially digestible fiber and (3) the lag time or time delay associated with the initiation of this hydrolysis. These attributes have been measured in masticate of animals consuming Coastal Bermudagrass hay. Masticated particles were separated into stem greater than 1600 microns, leaf greater than 1600 microns and undefined plant residues of 1600/1000, 1000/500, 500/250, 250/100, 100/20, and less than 20 micron size. Additionally, the greater than 1600 micron leaf, the greater than 1600 micron stem and the 1600/1000 micron plant material was also ground to pass a 1000 micron mesh laboratory mill to additionally study the effect of particle size reduction of these specific particles.

In general, a single exponential component model with time delay resulted in a superior statistical fit to the data as compared to other models which contained either (1) two exponential components, (2) omission of time delay or (3) the inclusion of a time dependency rate. In the case of particles greater than 1600, the leaf as compared to stem, was higher in potentially digestible fiber, digested at a slower rate and had a shorter time delay. Further grinding of greater than 1600 leaf and stem had relatively small effects upon digestible fiber and rate of digestion but had appreciable effects upon reducing time delay.

Forage particles smaller than 1600 were quite variable in their content of digestible fiber and rate of digestion and did not exhibit a distinct pattern. However, there was a trend for particles of 100/20 to be higher in digestible fiber and have a higher rate of digestion than other particles. The major effect of reducing particle size, whether by mastication or grinding via laboratory mill, was to reduce time delay.

PR-3946

Chromium-Mordanted and Rare Earth Marked Fiber for Particulate Flow Measurement

K. R. POND, A. G. DESWYSEN, J. H. MATIS AND W. C. ELLIS

Rare earth elements are used as paticulate flow markers because of their absorptive properties. The tenacity with which they remain bound to the feed residues of digestion and their possible translocation has been questioned. This criticism of the rare earths, however, may be due to method of marking the feedstuff. In initial work the material to be labelled was sprinkled or sprayed with a rare earth solution. Problems of ununiform labelling and applying concentration of marker beyond the binding capacity of the feedstuff may have been the prime reason for the translocation. To reduce these problems, the material may be labelled by soaking overnight followed by washing to remove unbound rare earth.

The chromium-mordant procedure has been pro-

posed in which the Cr is tightly bound to the fiber rendering it indigestible and presumbly inseparable during digestion. This experiment compares the passage of Cr-mordanted fiber to a rare earth (applied by the soaking and washed procedure) adsorbed on the same fiber.

Four cows fitted with esophageal cannulae were fed Coastal bermuda hay twice daily. After 7 days adjustment, a sample of masticated forage was taken via esophageal cannulae and 125 g prepared by the Cr-mordant procedure. A solution of $^{177}Lu(No_3)_3$ was then placed on the mordant fiber, allowed to soak overnight, washed thoroughly, and filtered. Twenty g of Cr-mordant — ^{177}Lu fiber in four capsules were dosed via esophageal cannulae at the beginning of the A.M. meal to each animal. Samples of feces were taken 0, 4, 8, 12, 16, 20, 24, 28, 32, 36, 40, 44, 48, 52, 60, 68, 72, 78, 84, 90, 96, 102, 108, 114, 120, 132, 144 and 156 hours post dose. Concentration of Cr in the feces was determined by neutron activation analysis.

Specific activity of each marker was fitted to a 2 compartment model for estimation of rate of passage (lambda 2). Lambda 2 was 3.73 *vs.* 4.59 (1), 6.95 *vs.* 7.51 (2), 3.03 *vs.* 3.23 (3) and 3.93 *vs.* 4.07 (4) for Cr and ^{177}Lu respectively for all cows (1-4). Additionally the rare earths Ytterbium and Terbium were absorbed on similar fiber and yielded similar rates of passage. It appears that the rare earths, if applied by the soaking and washing procedure, can be successfully used as particulate flow markers.

PR-3947

Rate of Passage Measurements as Affected by Dosing at Beginning or End of a Meal

K. R. Pond, A. G. Deswysen, J. H. Matis and W. C. Ellis

The voluntary intake of forage is related to its chemical composition and physical structure. To further understand how forage is utilized, more information is needed on its physical fragmentation during digestion because such processes determine passage rate of undigested residues through the digestive tract. Rate of passage through the digestive tract can be determind from a single dose of a marker. The dose can be given as a liquid drench or as a solid.

Markers applied to the consumed material can be used to accurately measure rate of passage, gastro-intestinal tract fill, and fecal output. To measure these, the marked material must be properly mixed with the reticulo-rumen contents. According to earlier studies on rumen motility and particulate movement in the retriculo-rumen, especially during a meal, the time of dosing can be of importance. Estimates obtained from the same animal can be different due to time of dosing.

The objective of this research was to determine if the time of dosing relative to a meal could effect the rate of passage estimates within the same animal. A masticated sample of the hay was obtained via esphageal cannulae, extracted with boiling water for 2 hours, throughly washed and dried. One hundred grams of the masticate was soaked in 800 mililiters (ml) of water containing $Tb(NO_3)_3$ equivalent to 6.9 g of Tb; and 100 g was soaked in 900 ml of water containing 200μci ^{160}Tb, both samples were soaked overnight. The masticate was filtered, washed thoroughly and a total of 25 g of Tb labelled masticate and 20 g of ^{160}Tb labelled masticate placed in 10 geltin capsules to be dosed via esophageal cannulae, to each animal.

The ^{160}Tb was dosed at the beginning of the A.M. meal and Tb was dosed at the end of the A.M. meal. Samples of feces were taken at 4 to 6 hr intervals for 6 days. Specific activity of ^{160}Tb was detected with a Ge(Li) detector, and concentration of Tb was determined by neutron activation analysis. The specific activities were fitted to a two compartment time dependent model where λ_2 represented the rate of passage from the rumen and through the rest of the gastro-intestinal tract and λ_3 represented the time from exiting the reticulo-rumen to first appearance in the feces.

Rates of passage (%/hr) for beginning and end of the meal dosing for the three animals were 6.094 *vs.* 2.831, 5.422 *vs.* 3.610 and 7.597 *vs.* 4.644. Time delay, λ_3(hr) were 25.9 *vs.* 17.2, 17.2 *vs.* 14.2 and 22.9 *vs.* 21.1. Rate of passage and time delay estimates were reduced by 42 percent and 20.5 percent, respectively, when dosing occured at the end of a meal. The dosing time is thus of real importance in estimating passage rates as well as a possible way to manipulate ruminal residence time. Trails with more animals fed a marked grain supplement at the beginning and the end of meal are currently in progress.

PR-3948

Marker Technique — A Two Marker Two Dose Method for Estimating Fecal Output, Fill and Flow

K. R. Pond, A. G. Deswysen, J. H. Matis and W. C. Ellis

Fecal output, gastro-intestinal tract fill, and flow can be estimated from the change in marker concen-

tration in the feces after a single dose. A less laborious and less expensive way of obtaining the marker concentration curve would be to use two biologically identical markers dosed at two different times. Each sample taken after dosing would account for two sampling times and hence reduce sample numbers by one half.

This experiment evaluated the biological similarity of various particles marked with different rare earths dosed at different times. Four Brahman × Jersey cattle (2 cows and 2 steers) fitted with esophageal cannulae were fed Coastal bermuda hay. Esophageal masticate was collected and marked with either 100μci of ^{169}Yb $(NO_3)_3$ or 2 grams (g) of Yb as Yb $(NO_3)_3$ per 21g and dosed in number 7 geletin capsules via esophageal fistula at 0 and 24 hours, respectively, following a pre-meal time. Similarly, wood pulp (Solca-floc) containing either 100μci ^{147}Nd or ^{141}Ce per 5g was dosed at 0 and 24 hours, respectively, following a pre-meal time. Similarily, wood chips containing either 2.2g Sm $(No_3)_3$ or 2.5g La $(NO_3)_3$ per 15g was dosed at 0 and 24 hours, respectively. Fecal samples were collected at 6 to 12 hours intervals for 156 hours after dosing. Rate of passage, fill and flow of each marker in each cow was estimated by a two compartment time dependent model.

Estimates obtained for the markers applied to the same material dosed at 24 hour intervals were equivalent. This indicates that rare earth marked particles administered at these times act biologically similar and a two marker two dose technique can be used to estimate fecal output, fill and flow. This marker technique has now been used in three grazing studies with 60-70 cattle each. The number of samples per animal has been reduced, so larger numbers of animals can now be evaluated with the same total number of samples.

PR-3949

Indigestible Fiber and Diet Selection by Yearling Cattle

H. LIPPKE

Close observation of grazing cattle indicates that they appear to engage in diet selection. The general assumption is that, within their ability to do so, they are selecting the most digestible plant parts available from the sward. However, cattle will frequently consume all the poor quality vegetation from fence rows in abundant winter pasture. Therefore, factors that govern diet selection and intake by grazing cattle are important in constructing useful models of the beef cattle enterprise.

A series of experiments was initiated to investigate the hypothesis that diet selection is governed by two "drives", one for energy and the other to fill the garstrointestinal (GI) tract.

In the first experiment, sorghum silage and freshly cut ryegrass were fed separately to yearling Brahman crossbred heifers stalled individually. Animals were either restricted in the amount of either ryegrass or sorghum they were offered, or received both forages *ad libitum*. Digestible organic matter (DOM) intake was used to indicate energy intake and indigestible neutral detergent fiber (INDF) was found to be a good indicator of fill for the GI tract. The heifers appeared to favor a diet containing about 16 percent INDF and 67 percent DOM. However, DOM intake was reduced if INDF was greater than 14 percent or less than 8 percent of the diet.

To check these results, this experiment was repeated with eight yearling Hereford x Angus steers offered both forages *ad libitum*. These steers selected a diet containing an average of 14 percent INDF and 68 percent DOM. Three other steers, offered only ryegrass (INDF = 5.6 percent) *ad libitum* consumed 18 percent less DOM than those also given sorghum silage.

In a third experiment, Hereford steers were offered sorghum and ryegrass silages. Most animals received restricted amounts of one or the other of the forages, but four steers were offered both feeds *ad libitum*. The free-choice diets selected had 10 percent INDF and 66 percent DOM. Again, DOM intake was depressed when INDF was higher than 14 percent or lower than 8 percent. These experiments establish the governing influence of INDF on diet selection and intake and the ranges of DOM and INDF values in diets selected by yearling cattle.

PR-3950

Supplemental Feeding and $MgCl_2$ Additions to the Water of Cattle Grazing Wheat Pasture

D. P. HUTCHESON AND D. J. UNDERSANDER

Magnesium supplementation has been widely practiced in calves grazing wheat pasture. However, high levels of magnesium added to free-choice mineral supplements may decrease the mineral consumption. Magnesium chloride ($MgCl_2$) is a water soluble form of magnesium and a good source of the magnesium ion. The following study was designed to determine the effectiveness of $MgCl_2$ additions to the

water for cattle grazing wheat pasture and to determine the effectiveness of methods of supplemental grain feeding.

Thirty-six calves were randomly allotted to 6 wheat pastures. The experimental design was a factional arrangement of treatments. The treatments were: no addition of $MgCl_2$, .28 percent $MgCl_2$ added to the water with no grain supplementation, grain supplemented at 5 pounds per head per day, and grain supplemented at 12.5 pounds per head fed three times a week. The grain supplement was whole shelled corn.

The test was conducted over a 76-day period using dryland wheat of the North Plains Research Field. Yearling steers weighing 523 pounds were used. The average daily gain for steers receiving $MgCl_2$ in the water was 1.74 pounds, whereas those not receiving $MgCl_2$ gained 2.13 pounds per day. Cattle fed grain three times a week had the highest daily gains at 2.43 lb., whereas steers fed no grain or fed grain daily gained 1.89 and 2.06 lb., respectively. The steers receiving $MgCl_2$ had the lowest water consumption of 4.3 gallons per head per day and the cattle not receiving $MgCl_2$ consumed 5.5 gallons per head per day. $MgCl_2$ added to the drinking water of cattle decreased water intake and performance.

PR-3951

Duration of Grazing Effects on Gastrointestinal Fill, Turnover, Digestibility and Voluntary Intake of Grazed Oat Pasture

J. P. Telford and W. C. Ellis

Summary

Measurements of the effects of duration of cattle grazing oat pasture were determined in three consecutive week long trials by Brahman × Jersey cattle of three distinct physiological sizes. The results from these trials indicate that with increased duration of grazing there are reductions in dry matter, fiber digestibility and voluntary intake. The decreases in digestibility were accompanied by increases in undigested dry matter fill (UDMF), longer retention time (RT) and reductions in rates of passage. The larger animals had slower turnover rates, longer retention times and greater *in vivo* digestibility of fiber and dry matter than medium or small sized cattle.

Introduction

Previous work with cattle grazing cool season annuals indicated that the level of performance was influenced by both frequency and duration of grazing (5). A major constraint of foraging cattle has been the unpredictable performance due to low forage intake. Many cattle graze on some variety of cool season annual forage during a portion of their lifetime. As a consequence, a limiting factor of the forages has been low digestible energy intake by cattle and the limited amount of energy contribution by the fiber within the diet. Voluntary intake of forage has been suggested to be restricted by physical factors when digestibility is less than 65 percent (4). Therefore, this study was conducted to quantify the effect of duration of grazing on intake, digestibility, gastrointestinal fill and flow of ingesta in cattle grazing forage oats.

Experimental Procedure

A uniform area of forage oats (Avena sativa) established the previous September was subdivided into six 900 square meter (m^2) plots. Plot size was based on previous estimates of forage growth rate and standing crop necessary to accommodate approximately 30 days grazing. Three consecutive 7 day collection periods were conducted during April and May when rapid changes were occurring in plant composition.

Each plot was allocated to two bi-fistulated (esophageal and ruminal) Brahman × Jersey cattle (two 360 kg dry cows [L], two 255 kg steers [M] and two 165 kg steers [S]). Esophageal extrusa samples were collected daily at about 4 pm, freeze dried and ground through a 2 mm screen. Forage dry matter was determined on alternate days from within a .25m^2 quadrant clipped at ground level.

A continuous infusion pump which delivered a .75 m solution of chromium diethylenetriaminepentaacetic acid (Cr DTPA) was inseted into the rumen cannula. In addition, each animal was given a single dose of 50 ml of $DyCl_3$ solution (454 g/liter) via rumen cannula (day zero of each of three collection periods) to serve as a flow and fill marker of undigested residues. After a seven day equilibration period, fecal collections were taken twice daily at 7 am and 5 pm then dried at 55° C and ground through a 2 mm screen.

Esophageal extrusa and standing crop samples were analyzed for dry matter, ash (1), neutral detergent fiber (NDF) (3) and *in vitro* 48 hour digestion adjusted by known *in vivo* digestibility (6). *In vivo* dry matter digestibility (DDM) was estimated by the ratio technique using the indigestible neutral detergent fiber (INDF) ratio obtained from 144 hour *in vitro* digestion of esophageal extrusa (EINDF) and fecal residues (FINDF). Fecal samples were further analyzed for dry matter, ash (1), and (a) Chromium and

(b) Dysprosium for calculations of fecal output from the two markers:

(a) Fecal Output (Kg DM/day) =

$$\frac{\text{ml/hour} \times 24 \times \text{gm Cr/ml}}{\text{gm Cr/gm feces DM}}$$

(b) Undigested dry matter Excreted = UDMF × K_2 × 24
(UDME kg DM/day)

$$\text{When UDMF} = \frac{\text{gm Dy dosed}}{\lambda_0 \text{ (initial [M] gm)}}$$
(GIT fill Kg DM)

and data were fitted to a model of concentration of Dy in fecal samples and where K_2 is the rate of passage of particulate matter exiting the gastrointestinal tract as $[K_2 (h^{-1})]$ (2).

Results and Discussion

Dates of collection and measures of standing crop and stocking pressure are presented in Table 1. Estimates of standing crop decreased ($P<.05$) in each period while stocking pressure increased ($P<.05$). These effects were a consequence of forage growth rate and removal by consumption and trampling. There were differences ($P<.05$) between animals of different sizes for forage removal rates. The larger cattle (360 kg) exerted a greater stocking pressure than the smaller cattle.

A major emphasis in these trials was placed on analysis of the fiber components of the diet since these appear closely associated with regulation of voluntary intake of the foraging animal. The content of neutral detergent fiber (NDF) and IVDDM of standing crop and esophageal extrusa and indigestible neutral detergent fiber (INDF) of esophageal extrusa are summarized in Table 2. There were consistent increases in fiber content of esophageal extrusa samples for all periods for each animal size. There were decreases in IVDDM with increasing NDF in the standing crop and esophageal extrusa samples with advancing periods. Similarly, INDF increased from period 1 through 3. Esophageal extrusa samples were consistently higher quality (lower fiber and higher digestibility) than standing crop. These data correspond with the increased amount of cell-wall formed at the expense of cell contents which appear to decrease overall plant dry matter digestibility.

Estimates of *in vivo* dry matter digestibility (DDM), neutral detergent fiber, gastrointestinal fill (GIT fill), rate of passage (Kp), and retention time are summarized in Table 3. The DDM and DNDF estimates increased from period 1 to period 2 and then decreased in period three. It is interesting to note that there was a 2.54 cm rain near the end of period 1 resulting in a flush of new tiller growth for period 2. However, there was not sufficient regrowth material to maintain a high quality of forage for period 3. The decreased DDM and DNDF in period 3 was associated with heavier stocking presure, higher NDF and lower IVDDM of standing crop than other periods. The quantity of regrowth forage and current standing crop may not have been sufficient to allow maximal consumption of highly digestible selectable plant parts. The differences could explain the higher NDF, INDF, and lower IVDDM of esophageal extrusa observed in period 3 of this study.

There was a tendency for the larger cattle to more completely digest both DDM and DNDF than medium size cattle, which digested more than small cattle. The increased digestibilities for the larger cattle occurred as a result of increased retention time and decreased rate of passage. There was a 26 percent decrease in rate of passage from period 1 to 2 and an additional 8 percent decrease between period 2 to 3. There was a corresponding trend noted for retention times becoming longer from period 1 vs 2 vs 3. The larger cattle also exibited longer retention times than medium or small cattle. Therefore, time could help explain the inverse relation demonstrated for DDM and DNDF since larger cattle digested forage to a greater extent.

The larger cattle exerting greater grazing pressure, tended ($P<.05$) to retain undigested dry matter

TABLE 1. COLLECTION DATES, STANDING CROP (SC) AND STOCKING PRESSURE (SP) ASSOCIATED WITH OAT FORAGE

Period	Collection Date	Cattle Size							
		Large		Medium		Small		Mean	
		S.C.	S.P.	S.C.	S.P.	S.C.	S.P.	S.C.	S.P.
		Kg DM/ ha	Kg DM/Plot/ 100 Kg B.W.	Kg DM/ ha	Kg DM/Plot/ 100 Kg B.W.	Kg DM/ ha	Kg DM/Plot/ 100 Kg B.W.	Kg DM/ ha	Kg DM/Plot 100 Kg. B.W.
1	Apr 28	4229	10.69	4844	16.97	4854	27.43	4642[a]	18.36[a]
2	May 6	3765	10.00	4546	16.27	4280	24.20	4197[b]	16.82[b]
3	May 14	2541	6.60	3603	13.24	2972	16.92	3039[c]	12.25[c]
			$\bar{X}$ S.C. 3512[b] S.P. 9.10[a]		4331[a] 15.49[b]		4035[a] 22.85[c]		

[abc]Means on the same row or column with different superscripts are significantly different ($P<.05$).

TABLE 2. MEAN CONTENT FOR NEUTRAL DETERGENT FIBER (NDF), INDIGESTIBLE NEUTRAL DETERGENT FIBER (INDF) AND *IN VITRO* DRY MATTER DIGESTIBILITY (IVDDM) OF STANDING CROP AND ESOPHAGEAL EXTRUSA FROM FORAGE OATS

		Cattle Size							
		Large		Medium		Small		Mean	
Item	Period	Stand Crop	Esoph Extrusa	Stand Crop	Esoph Extrusa	Stand Crop	Esoph Extrusa	Stand Crop	Esoph Extrusa
		% DM							
NDF	1	71.23	65.68	71.53	63.22	71.19	64.94	71.32[b]	64.61[b]
	2	71.01	67.49	72.56	63.72	72.59	65.02	72.03[ab]	65.41[b]
	3	73.62	68.27	73.26	66.28	73.09	67.81	73.32[a]	67.45[a]
	$\bar{X}$	71.95[a]	67.15[a]	72.45[a]	64.41[b]	72.26[a]	65.92[ab]		
INDF	1		19.14		18.20		20.66		19.33[b]
	2		19.62		20.73		20.48		20.28[b]
	3		24.58		21.33		26.18		24.03[a]
	$\bar{X}$		21.02		20.00		22.36		
IVDDM	1	51.50	61.01	49.93	61.45	50.54	60.92	50.24	61.13
	2	48.57	59.65	46.93	59.19	46.09	59.75	47.02	59.53
	3	47.56	57.87	45.01	57.45	46.00	57.68	46.19	57.67
	$\bar{X}$	49.21[a]	59.51[a]	47.11[b]	59.36[a]	47.54[b]	59.46[a]		

[abc]Means in the same row with different superscripts are significantly different (P<.05)

6.2 percent longer than medium and 10.8 percent longer than small cattle, which had the lightest grazing pressure. These values of retention time correspond to slower rates of pasage for larger cattle but increased *in vivo* digestibility due to the greater residence time. Smaller cattle with the lightest grazing pressure, had lower *in vivo* digestibility, which was associated with faster rates of passage and shorter retention time.

TABLE 3. MEAN VALUES OF *IN VIVO* DRY MATTER (DDM), NDF (DNDF), RATE OF PASSAGE, GIT FILL AND RETENTION TIME

Item	Period	Cattle Size			
		Large	Medium	Small	Mean
DDM	1	61.67	57.56	55.34	58.19[b]
%	2	65.36	59.54	58.56	61.15[a]
	3	57.10	61.25	52.32	56.89[c]
	$\bar{X}$	61.38[a]	59.45[b]	54.41[c]	
DNDF	1	68.23	67.31	64.03	66.52[b]
%	2	72.10	66.81	67.94	68.95[a]
	3	65.55	67.54	60.42	64.50[c]
	$\bar{X}$	68.63[a]	67.22[b]	64.13[c]	
GIT Fill	1	.643	.587	.989	74[b]
(UDMF)	2	.845	.815	1.234	.97[a]
(Kg DM/	3	.991	.733	1.54	1.09[a]
100 kg BW)	$\bar{X}$	.82[b]	.71[a]	1.25[b]	
Rate of	1	.047	.056	.056	.053[a]
Passage	2	.040	.039	.038	.039[b]
(hr^{-1})	3	.031	.046	.031	.036[c]
	$\bar{X}$	.040[b]	.047[a]	.042[b]	
Retention	1	36.08	30.53	35.84	33.31[c]
(hr)	2	39.10	38.53	30.74	36.12[b]
	3	46.22	44.98	41.79	44.30[a]
	$\bar{X}$	40.47[a]	37.98[b]	36.12[c]	

[abc]Means in the same row or column with different superscripts are significantly different (P<.05).

Total gastrointestinal fill increased an average 31 percent from period 2 to 3. The increased fill (UDMF) associated with advancing forage maturity observed in this study corresponded to reduced turnover rates and increased retention times. The exact nature of the effect of fill on declining forage quality is not known, but there appears to be some flexibility or elasticity within the animal to increase fill and flow rate of undigested residues. The exact site or sites is not apparent since sampling occured only from the feces.

Estimates of fecal output and voluntary intake estimated by single dose (Dy) or continuous infusion (Cr) are presented in Table 4. There was good agreement (r = .85) for fecal output estimates by

TABLE 4. MEAN VALUES OF FECAL OUTPUT (FO) AND VOLUNTARY INTAKE (VI) MEASURED BY SINGLE DOSE (DY) OR CONTINUOUS INFUSION (CR)

		Cattle Size			
Item	Period	Large	Medium	Small	Mean
		Kg DM/100 Kg BW			
F.O.	1	.72	.79	1.33	.95[a]
(DY)	2	.83	.76	1.12	.90[a]
	3	.75	.81	1.14	.90[a]
	$\bar{X}$	.77[b]	.79[b]	1.20[a]	
F.O.	1	.88	.77	1.09	.91[a]
(Cr)	2	.88	.86	.94	.89[a]
	3	.90	.86	1.14	.97[a]
	$\bar{X}$	.89[b]	.83[b]	1.06[a]	
VI	1	1.88	1.86	2.98	2.24[a]
(DY)	2	2.39	1.88	2.71	2.33[a]
	3	1.74	2.09	2.38	2.07[a]
	$\bar{X}$	2.01[b]	1.94[b]	2.69[a]	
VI	1	2.29	1.81	2.43	2.18[b]
(Cr)	2	2.54	2.11	2.28	2.31[a]
	3	2.10	2.12	2.40	2.21[ab]
	$\bar{X}$	2.31[a]	2.01[b]	2.37[a]	

[ab]Means in the same row or column followed by different superscripts are significantly different (P<.05).

either continuous infusion of Cr EDTA or by dilution and turnover (K_2) of $DyCl_3$ and did not appreciably change with increasing forage age using either method. However, the smaller-sized cattle under lighter grazing pressure had higher fecal outputs per unit body weight than did either large or medium sized cattle.

The voluntary intake estimated by either method ranked period 2 higher than the other two periods, and closely followed the pattern in DDM and DNDF. In general, the greater value of DDM and DNDF in period 2 came as a consequence of new tiller growth from rain later in period 1 and was reflected in greater voluntary intake even though total standing crop and stocking pressure had been altered (Table 1). However, digestibility alone could not explain the difference accounted for in intake. These results indicate the sensitivity of plant and animal response under continuous grazing to rain and the dynamic effect rate of forage removal has upon its subsequent pasturing value. It is interesting to note the response stocking pressure has on voluntary intake. Estimates of intake by either technique gave approximately the same response. Intake of the larger cattle peaked in period 2, then declined, while the mid-sized cattle steadily increased from period 1 to 2 to 3 and the small cattle tended to decrease from period 1 to 2 to 3. Each group of cattle reacted uniquely to their continuous grazing paddocks. The medium and larger animals exerted a greater stocking pressure and had, as a response, lower intakes than did the smaller cattle. There were consistent declines in forage quality between periods since fill did not appear to present limitations to intake. In contrast, the larger cattle in period 2 only approached the intake values of the smallest cattle, suggesting that forage digestibility may have been a limiting factor.

There appears to be some latitude in flexibility of GIT fill that allows animals to accommodate some variation in fecal output. Increases in GI fill due to increasing forage age coincide with slowed turnover rates and increased retention time. Variations in Kp occurred which may have been independent of rate of digestion (Kd) resulting in digestion (Kd/Kd + Kp). This could occur since fecal output (FOUT) is a major determinant of intake (INTK = FOUT/1-DDM). In this study fecal output was determined by UDME = UDMF × Kp. Therefore, variation in fecal output could occur independently of changes associated with changes in digestion. Hence, intake would not necessarily be solely associated with digestion. The increases in G.I. fill due to forage age coincide with slowed turnover rates and increased retention time, while fecal output remained fairly constant. The variations in rate of passage (Kp) that occurred may have been independent of rate of digestion (Kd) since both are components of digestion (Kd/Kd + Kp). In this study, fecal output was determined by UDME = UDMF × Kp × 24. Therefore, variation in fecal output could occur independently of changes associated with changes in digestion. Hence, intake would not necessarily be solely associated with digestion but could be greatly influenced by physical attributes of the forage consumed as supported by results in this study. Greater insight into the aspect of physical breakdown of forages should add to our understanding of those factors regulating voluntary intake of grazing cattle.

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PR-3952

Intraruminal Responses to Monensin in Cattle Grazing Forages

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Summary

In one trial involving Bermuda grass of 58 percent DOM, monensin increased ($P<.01$) ruminal turnover rate of forage solids (13 percent), microbial matter (55 percent) and water soluble solute (71 percent) and was accompanied by a non-significant increase (12 percent) in rumen content of organic matter. In a second trial, involving Bermuda grass of 48 percent DOM, supplemental monensin was associated with a non-significant increase in the turnover rate of forage solids (20 percent), microbial matter (10 percent) and rumen content of organic matter (14 percent) and a 21 percent reduction in turnover of water soluble solutes. Similar responses were observed for turnover to feces and increases in gastrointestinal fill of undigested matter. In a third trial involving grazing of the seed head of oats, the feeding of monensin was not associated with any effect upon ruminal or gastrointestinal turnover of solids, microbial matter or solutes, but was associated with a 12 percent increase in rumen contents of organic matter. When results of the three trials were combined, the

effects of monensin upon rumen content of organic mater was statistically significant ($P<.05$) and averaged 13 percent more than controls. These results suggest monensin may have variable effects upon ruminal turnover, but rather consistent effects upon rumen fill. The results are consistent with other observations and appear to explain, at least in part, the increased feed intake and consequently, gains that forage fed animals make when receiving supplemental monensin.

Introduction

It is well established that grazing cattle fed monensin have increased gain in the order of 0.1 kg per day. The mechanism of this increased gain has not been established. Previous studies (1) have indicated monensin has a number of effects upon digestion. These effects include an increase in digestibility of Bermudagrass of approximately 4 percent, an increase in fecal output in the order of 7 to 12 percent and an increase in fill of undigested material within the gastrointestinal tract in the order of 10 to 20 percent. These observations suggest the increased gains due to monensin may be the result of an increase in fill which allows a greater fecal output and, when combined with increased digestibility, an increase in forage intake. The previous measurements of gastrointestinal fill are indirect and the current experiments were designed to provide a more direct measurement of the effects of monensin upon the fill of organic matter within the rumen and turnover or rate of passage of components of the rumen organic matter to the lower tract.

Experimental Procedures

Measurements of digestibility of grazed forage were made as earlier described by Pond and Ellis (1). Together with these measurements of digestibility, measurements of fecal output, mean gastrointestinal fill and turnover of solids was made as described by Ellis *et al.* (2).

Turnover of solutes was measured from the exponential decline in chromium concentration in rumen dry matter following a single pulse dose of chromium DTPA (Diethylenetriaminepentaacetic acid). Turnover of microbial matter was measured by giving a single pulse dose of sulphur-35 sulfate and following the concentration of organically bound sulphur-35 subsequent to this pulse dose.

The pulse dose was applied to samples of esophageal extrusa from animals grazing on the test forage. This was obtained three days prior to pulse dosing and was from the same animals which were grazing on the test site. They were introduced into the rumen at dose time and samples removed 6, 9, 12, 18, 24, 30, 36, 42, 48, 60, 72, 84, and 96 hours thereafter.

Mature Brahman × Jersey cows having established rumen and esophageal cannulae were used in the three experiments. These animals averaged approximately 500 kg body weight. In the first trial, 8 animals were employed with 4 receiving a daily supplement of 500 g of a grain mixture and 4 animals receiving 500 g of a grain mixture with 100 mg monensin. These cows grazed on Bermuda grass which was subsequently determined to have a digestible organic matter content (DOM) of 58. In the second trial, 11 animals were employed, 5 animals receiving 500 g daily of cottonseed meal and 6 animals receiving 500 g daily of cottonseed meal containing 300 mg of monensin. In the second trial cows grazed frosted bermudagrass which was subsequently determined to contain 48 percent DOM. The third trial involved 8 animals, 4 receiving 500 g of a grain mixture and 4 receiving 500 g of a grain mixture containing 300 mg of monensin. Cows in this trial grazed oats which had headed out, and the diet was predominately composed of the seed heads which were determined to be 60 percent DOM.

Results

Results of the first trial are summarized in table 1. Monensin increased ($P<.05$) the turnover rate of

TABLE 1. RESULTS OF THE FIRST TRIAL

Item	Treatment		M-C
	Control (C)	Monensin (M)[a]	C
			%
No. Animals	4	4	
Dig. of O.M., %	62.5	63.8	2.1
Dig. of N.D.F., %	70.7	69.7	−1
R.O.M. fill, kg/100 B.W.	1.54	1.69	10
Fractional ruminal turnover, hr^{-1}			
Yb - solid	.046	.052	13*
^{35}S - bound	.040	.062	55*
Cr - DTPA	.103	.176	71*
Fecal output, kg/100 kg B.W.	0.934	1.095	15*
Forage intake, kg/100 kg B.W.	2.491	3.025	21*
DOM intake, kg/100 kg B.W.	1.557	1.930	24

[a]100 mg/hd/day or 8 PPM
*(P = < .01)

rumen forage solid material 13 percent as indicated by the ytterbium labelled solid material. This result is in contrast to earlier results in which monensin reduced turnover rate of forage solids in the gastrointestinal tract (1). Monensin statistically increased ($P<.05$) the turnover of organically bound sulphur 35 by 55 percent and that of water soluble solute (Chromium DTPA) by 72 percent. Although the rumen fill was increased by 10 percent, this increase was not statistically significant.

The results of the second trial are summarized in table 2. None of the effects of monensin reported in table 2 are statistically significant due to the much higher within animal variation encountered in this trial. However, the feeding of monensin was associated with an increase in ruminal turnover of solids and bound sulphur 35 and an increase in rumen fill. The magnitude of the increase in rumen fill was similar to that for gastrointestinal fill as indicated by fecal output and rate of passage of the ytterbium labelled solids. In contrast to the first experiment, the turnover of chromium DTPA in the rumen was reduced. This reduction was apparent both in the rumen and in the feces.

Results of the third trial are summarized in table 3. Monensin had no consistent effect upon turnover of either solids or bound sulphur 35 as measured either in the rumen or feces. As in the other trials, there was a non-significant increase in rumen fill. This increase in rumen fil was of the same order of magnitude as that observed in the other two trials. When results of the three trials were combined, the increase in rumen fill averaged 12 percent and was significant ($P < .05$). This mean increase in rumen fill was of the same order of magnitude as previously observed for increase in gastrointestinal fill. The increase in rumen fill reported here is a more direct measure of fill and therefore more directly substantiates this effect of monensin. The similarity in the magnitude between fill estimated by direct measurement in the rumen and indirect measurement in the feces substantiates the indirect method of estimating increase fill from fecal output.

The more direct measurement of increased rumen fill reported here adds further support to the earlier suggestion that the increased fecal output due to monensin appears associated with an increase fill in the gastrointestinal tract. Due to the comparatively larger volume within the rumen, it was earlier assumed this was the major site of increased fill within the gastrointestinal tract. The means whereby monensin allows the grazing animal to accumulate greater fill is however, not defined by these experiments. Most researchers conceive the volume of the gastrointestinal tract to be constrained by the space available in the abdominal cavity of the animal. Possibly, monensin may influence the feeding pattern whereby the animal maintains a greater amount of fill throughout the day by more frequent eating. No observations were made in the current studies which might be related to this mechanism, however.

The increased ingesta turnover observed in the first two trials is in contrast to earlier reports in which monensin either reduced rate of passage or had no effect. In the first trial, monensin had the greatest numerical effect upon solute turnover (71 percent). The effect upon turnover of bound sulphur-35 (55 percent) was intermediate to that for the solute and for the solid (13 percent). The intermediate nature of sulphur-35 response might be attributed to the fact that certain microorganisms are free floating and would have turnover rates similar to that of solutes while other microorganisms are adherent to feed particles and have turnovers similar to that of the solids.

The first trial was distinctly different from the other two trials in that the effects of monensin upon ruminal turnover was statistically significant ($P<.05$).

TABLE 2. RESULTS OF SECOND TRIAL

Item	Treatment		M-C
	Control (C)	Monensin (M)[a]	C
			%
No. Animals	5	6	
Dig. of O.M., %	47.5	49.1[b]	3.4
Dig. of C.P., %	56.3	55.3	−1.8
F.O.M. fill, kg/100 kg B.W.	1.196	1.314	9.9
R.O.M. fill, kg/100 kg B.W.	2.188	2.500	14.3
Fractional turnover, hr^{-1}			
Yb - solid, feces	.0454	.0462	1.8
Yb - solid, rumen	.0368	.0442	20.1
^{35}S - bound, feces	.0233	.0233	0
^{35}S - bound, rumen	.0251	.0275	9.6
Cr - DTPA, feces	.1258	.0907	−27.9
Cr - DTPA, rumen	.0980	.0766	−21.8
Fecal output, kg/100 kg B.W.	1.148	1.330	15.9
Forage intake, kg/100 kg B.W.	2.190	2.611	19.2
DOM intake, kg/100 kg B.W.	1.042	1.279	22.7

[a]300 mg/hd/day or 23 PPM

TABLE 3. MEAN UTILIZATION OF FORAGE, THIRD TRIAL

Item	Treatment		M-C
	Control (C)	Monensin (M)[a]	C
No. Animals	4	4	
Apparent dig. of O.M., %	65.38	67.47	3.2
Apparent dig. of C.P., %	33.44	32.92	−1.5
Mean Rumen fill, kg O.M./100 kg B.W.	2.613	2.923	11.9
Mean U.O.M. fill, g. O.M./100 kg B.W.	.761	.638	−16.1
Fractional turnover, hr^{-1}			
Yb - solid, rumen upper strata	.059	.057	−3.4
Yb - solid, rumen lower strata	.060	.064	6.7
Yb - solid, feces	.062	.063	1.6
^{35}S - bound, rumen upper strata	.054	.042	−22.2
^{35}S - bound, rumen lower strata	.045	.060	33.3
^{35}S - bound, feces	.056	.047	−16.1
Fecal output, kg O.M./100 kg B.W.	1.093	.979	−10.4
Forage intake, kg O.M./100 kg B.W.	3.153	3.010	−4.5
DOM intake, kg DOM/100 kg B.W.	2.061	2.031	−1.5

[a]300 mg/hd/day or 20 PPM

The reason for this difference is not apparent. However, it should be pointed out the dose rate of monensin was lower in the first trial as compared to others. Concentration of monensin in the dry matter intake in the first trial was about 15 parts per million of the diet whereas in the other trials it was 30 parts per million. Although these considerations suggest a possible explanation for differences in the first trial, other differences existed which may also have contributed. Differences such as digestibility of Bermudagrass and other unrecognized differences may be causal of the unique results.

Regardless of the cause for the more rapid ingesta turnover for the first trial, this conceivably would be quite beneficial in terms of the animal protein nutrition. For example, increased turnover of sulphur bound-35 would reflect an increased microbial growth rate and supply of microbial protein to the lower intestinal tract. Such an increased turnover might contribute to the protein sparing effect of monensin that has been previously reported.

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Ionophore Effects on Growth Rates of Grazing Stocker Cattle

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Summary

Crossbred beef heifers were used in two grazing studies to assess the merit of ionophores, Monensin and Lasalocid, in enhancing rate and efficiency of gain of cattle grazing small grain winter pastures. Pastures were either rye grass, wheat, or oats seeded in the fall and grazed from March through June. While cattle in both studies responded to Lasalocid, the optimal level for maximum response ranged from 50 to 200 mg/day. Gain response suggested a curvilinear relationship to level of ionophore with lower responses for cattle fed higher levels (300, 400 mg) of Lasalocid daily. Monensin effects on rate of growth were greatest overall for cattle fed 200 mg daily.

Introduction

It is well documented that the inclusion of ionophores, (polyether antibiotics), either Monensin or Lasalocid, in rations for feedlot cattle improves feed and energetic efficiency and, in some cases, rate of gain. While these ionophore effects are well documented for feedlot cattle, responses in grazing stocker and herd replacement cattle are not as clearly understood. The response is dependent on the diet net energy density and digestibility as well as level of ionophore provided. Modes of action include a reduction in maintenance energy requirements (1,2), and changes in intake, digestive tract fill and digesta flow (3), the latter being dependent on diet digestibility. The summation of these effects determines energy availability and animal energy requirements and thus rate, composition, and energetic efficiency of growth. These animal functions were addressed in

two studies with grazing heifers to provide data for integrating the interpretation of digestive tract function and cattle growth and development responses to ionophores.

Experimental Procedure

College Station

Rye grass-wheat pastures were seeded in September, 1980 and established by January 1, 1981. Sixty Brangus and Simmental × Charolais heifers were managed in two groups of 30 head and rotated daily between two 25-acre pastures. All cattle were individually fed supplements containing the appropriate compound and level in 1 lb of ground milo daily. While supplement intake was not a problem, pasture availability was, and required reduction of animal numbers to 30 head following day 64. The remaining 30 head were carried through 105 days of grazing. Ionophore treatments included none, Monensin at 100 or 200 mg/hd/day, or Lasalocid at 100, 200 or 400 mg/hd/day. Body composition was measured through isotope dilution procedures with deuterium oxide infusion of cattle at initiation and termination (4). Grazed forage intake and kinetics of digesta flow were assessed at two times during the study following introduction of rare earth markers and collection of appropriate fecal samples.

McGregor

Oats pastures were seeded in September of 1980 and grazing was initiated in March of 1981. One hundred beef crossbred heifers were managed as one group and rotated through pasture plots. All cattle were individually fed 1 lb of ground milo containing appropriate levels of Lasalocid to provide 0, 50, 100, 200 or 300 mg/hd/day. Cattle were infused with deuterium oxide for initial and terminal measurement of body composition. Indigestible fiber and introduced rare earth markers were employed in estimating grazed forage and energy intake as well as digestion and digesta passage parameters.

Supplement refusal was a problem with some animals and data from these animals are not included in the analyses presented.

Results and Discussion

Responses for the 58 heifers completing 64 days of the College Station study are listed in table 1. Rates of gain in all cattle were excellent, with control cattle gaining 2.3 lb/day, and none of the treatment groups differed significantly. Responses to Monensin at either 100 or 200 mg/day were similar; rates of gain were 7.8 and 6.1 percent greater than those of control cattle. Lasalocid response indicated a dose dependency, with highest rates of growth for cattle fed 200 mg/hd/day; these cattle were 10.4 percent above the control cattle. Cattle fed 100 mg/day gained similarly to controls and cattle fed 400 mg/day gained similarly to Monensin fed cattle, or 6.9 percent faster than controls. Growth rates for the 30 cattle completing the total 105 days are lited in table 2. Since forage availability decreased substantially following the 64 day weigh period, rates of gain were expected to decrease, reflecting the limited feed supply. The response over the total 105 days reflected these limita-

TABLE 1. GROWTH OF HEIFERS IN RESPONSE TO IONOPHORES DURING 64 DAYS OF GRAZING, COLLEGE STATION

	Control	Monensin (mg/day)		Lasalocid (mg/day)			
Item		100	200	100	200	400	SE
No. Cattle	9	10	9	10	10	10	
Initial wt., lb	461.9	449.1	441.9	449.6	445.4	451.1	18.8
Interim wt., lb, 64 days	609.9	608.4	598.5	596.9	608.6	609.5	22.1
ADG, 64 days[ab]	2.31	2.49	2.45	2.30	2.55	2.47	.13
Percent response		7.8	6.1	---	10.4	6.9	

[a]Based on initial and 64 day shrunk weights.
[b]Analyses of variance indicated no significant treatment effects.
[c]Standard error.

TABLE 2. OVERALL GROWTH RATES OF GRAZING HEIFERS, COLLEGE STATION

	Level/day (mg)						
Item	Control	Monensin 100	Monensin 200	Lasalocid 100	Lasalocid 200	Lasalocid 400	SE
No. Cattle	5	5	5	5	5	5	
Initial wt. lb	450.7	439.7	447.1	450.2	422.5	449.8	31.2
Final wt. lb, 105 days	624.7	602.0	627.3	610.1	608.4	629.1	30.5
ADG, 105 days[ab]	1.66	1.55	1.72	1.52	1.77	1.71	.15
Percent response, 105 days			3.6		6.7	3.6	

[a]Based on initial and 105 day shrunk weights.
[b]Analysis of variance indicated no significant treatment effects.
[c]Standard error.

TABLE 3. LASALOCID EFFECTS ON GROWTH RATES OF GRAZING HEIFERS, McGREGOR

Item	Control	Lasalocid (mg/day)				
		50	100	200	300	SE[d]
No. Cattle	14	14	15	16	17	
Initial wt., lb	475.6	474.6	497.5	481.1	489.2	19.7
ADG, 84 days	1.88[b]	2.26[c]	2.13[bc]	2.12[bc]	2.19[c]	.08
Percent response, 84 days		20.2	13.3	13.3	16.0	
Final wt, 100 days	587.9	615.1	626.5	609.1	622.7	19.0
ADG, 100 days	1.12[b]	1.41[c]	1.29[bc]	1.28[bc]	1.34[c]	.07
Percent response, 100 days		25.9	15.2	14.3	18.8	

[a]Based on initial and 100 day shrunk weights.
[bc]Values in same row with different superscripts differ (P<.05).
[c]Standard error.

tions, with overall rates of gain much below the 64 day average. There was no response to either 100 mg Monensin or 100 mg Lasalocid; rates of gain with 200 mg Monensin or 400 mg Lasalocid were 3.6 percent greater than those of control cattle. Lasalocid at 200 mg/hd/day reflected the greatest response, with rates of gain 6.7 percent above those of control cattle. However, average weights of all cattle at 105 days were only marginally greater than 64 days weights, reflecting the maintenance level of grazed forage available during the last 41 days of the study, which had a large impact on overall performance.

Forage available for grazing in the McGregor study also diminished with time, especially after 84 days and growth rates reflected these limitations (table 3). While 100 heifers were allotted to this study, 24 refused to eat appreciable amounts of supplement and were excluded from this summary. Positive responses in rates of gain were observed for all levels of Lasalocid. Heifers responded greatest to the 50 mg level, with 20.2 and 25.9 percent increases in daily gain above rates of gain for control heifers at 84 and 100 days, respectively. The response was dose dependent, with lesser effects on rate of gain for cattle fed 100, 200, or 300 mg Lasalocid daily.

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PR-3954

Forage Utilization Systems for Wintering and Breeding Replacement Heifers

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Summary

Seven heifers were allotted, at weaning, to each of two replicates of the following treatment groups (n = 56); (HSUP) drylot from November 21 to March 12 with hay + 5 lb/hd/da of feed supplement (4:1 ground milo-cottonseed meal); (HCSM) drylot from November 21 to March 12 with hay + .5 lb/hd/da cottonseed meal (CSM); (FULL) full-time grazing of wheat-ryegrass pastures from November 21 to May 21; (PART) hay + part-time grazing of wheat-ryegrass pastures from December 6 to May 21. HSUP and HCSM groups were moved from drylot to ryegrass-arrowleaf clover pasture on March 12 and remained until May 21. All four groups were placed on a bermudagrass-ryegrass-arrowleaf clover pasture on May 21 and exposed to fertile bulls for a 56-day breeding season.

Average daily gain was highest (P<.001) for heifers in HSUP with 1.24 lb/hd/da, followed by HCSM, FULL, and PART groups with 1.15, 1.15, and .81 lb/hd/da, respectively. Differences among treatment groups were noted for height (P<.10), length (P<.05), and condition score (P<.001). Age at puberty was lowest (P<.05) for heifers in HSUP and highest for heifers in PART. Weight at puberty, however, was highest (P<.05) for heifers in HCSM at 703 lb, and was followed by HSUP, FULL, and PART at 644, 615, and 600 lb, respectively. Pregnancy rates of heifers in HSUP and HCSM groups were higher (P<.01) at 93 and 92 percent, respectively, than pregnancy rates of heifers in FULL and PART groups at 64 and 54 percent, respectively. Average daily gain

($P<.001$) and body condition score ($P<.01$) were the most important physical traits affecting puberty in this trial.

Introduction

Development of replacement heifers is often expensive, frustrating, and disappointing because of failure to get the heifers pregnant after an extended feeding-pasturing period. Since the majority of replacement heifers at spring-summer bred, fall-weaned heifers must be prepared for wintering as rapidly as possible. Previous research has shown that there are certain age-weight relationships that must be met in order to have heifers impregnated. Since these relationships vary between breeds as well as within breeds, the feeding period during the winter months should be planned to allow adequate heifer growth to meet requirements for first estrus. This study was initiated to evaluate methods of utilizing forage-land resources in the process of developing replacement heifers. Methods tested allow maximum or optimum use of forage surplus in the spring-summer period via programmed grazing, and use of compensatory gain as a biological and economical advantage.

Experimental Procedure

Fifty-six ½ Simmental × ¼ Brahman × ¼ Hereford heifers were allotted to two replicates of four treatment groups on November 9. Each replicate consisted of seven heifers and one sterile marker bull. Two treatment groups remained in drylot (with different rations) from November 9 until a ryegrass-arrowleaf clover pasture was available for grazing. Grazing of the ryegrass-clover pasture was initiated on March 12. One drylot ration consisted of *ad libitum* baled hay plus 5 lb/hd/da of a 4:1 milo-cottonseed meal (CSM) mixture (HSUP). The other drylot ration consisted of *ad libitum* baled hay plus .5 lb/hd/da of CSM (HCSM). Another heifer group had access to full-time, continuous grazing of wheat-ryegrass from November 21 until plant maturity (May 21) (FULL). Stocking rate in this group was 2 hd/ac. The last group received *ad libitum* round baled hay plus a part-time grazing sequence on sod-seeded wheat-ryegrass pasture (PART). Heifers initially grazed for 2 hours/hd/da until sufficient forage growth allowed for additional grazing time. Stocking rate in this group was 6 hd/ac. All replicates of all groups were separated from November 9 until May 21. On May 21, all groups were combined into a single herd to allow access to a common forage diet (ryegrass-clover-bermudagrass), and exposure to two fertile Brahman bulls for a 56-day period (May 21 to July 16).

The following forage data was taken: dry matter availability, grazing pressure and stocking rate, percent *in vitro* dry matter digestibility, percent protein, and quantity of hay offered. Animal data taken was: average daily gain; condition score; height and length (measured on November 9, March 12, May 21, and July 16, or at puberty); age at puberty; weight at puberty and pregnancy rate. All heifers were weighed and condition scored at 28-day intervals. Puberty was defined as the first estrus after which a palpable corpus luteum was present. Pregnancy was determined via rectal palpation 56 days after removal of the fertile bulls (September 8).

Results and Discussion

Heifers assigned to the *ad libitum* baled hay plus .5 lb/hd/da cottonseed meal (HCSM) consumed an average of 15.2 lb hay/hd/da; whereas, heifers in the hay-supplement group (HSUP), consumed an average of 12.6 lb hay/hd/da. Differences in hay consumption were due primarily to supplemental feed. The part-time grazing plus round baled hay group (PART) consumed the least amount of hay during the trial (7.9 lb/hd/da). These consumption differences may be due in part to the nature in which hay was offered (hay bunk *vs* on the ground), and the nutritive value differences between the baled hay *vs* round baled hay. The *in vitro* dry matter digestibility (IVDMD) of the conventional rectangular bales averaged 52 percent; whereas, the round baled hay averaged only 42 percent during the trial period. This 10 percent difference in IVDMD amounts to approximately 20 percentage unit advantage for the rectangular baled hay. Of equal importance was the fact that the rectangular bales had a protein content of 14.5 percent, while the round bales had protein content of 10.3 percent. This 4.2 percent difference in protein represented an approximate 30 percentage unit change in protein between the two types of hay. Although the original objective of this trial was to include the comparison of heifers wintered on rectangular bales *vs* round bales, the wide range in nutritive value of the two hay types may have confounded the interpretation of the data. The consumption data presents, however, a very vivid and dramatic example of the influence of nutritive value on hay intake. Depending upon the quality of hay at baling and conditions during storage, these nutritional differences between rectangular *vs* round bales are not uncommon.

Wheat-ryegrass forage was available in sufficient quantity so that animal peformance was not adversely affected due to restricted intake (Table 1). The heifers assigned to the FULL group had more forage available per unit body weight than did those heifers in the PART group. This was primarily due to the original design of the trial which was to evaluate heifer performance and efficient forage utilization. Thus, grazing pressure and stocking rate were considerably higher for the PART heifers as compared to the FULL heifers. Dry matter and nutritive value of forage available to the combined groups of HSUP and HCSM after removal from drylot are shown in Table 2. The decline in IVDMD is a reflection of the increase in bermudagrass in the sward; whereas, the maintenance of the relatively high protein level is due to the influence of arrowleaf clover in the mixture.

TABLE 1. DRY MATTER (DM), *IN VITRO* DRY MATTER DIGESTIBILITY (IVDMD) AND PROTEIN OF AVAILABLE FORAGE IN PADDOCKS GRAZED BY FULL-TIME (FULL) AND PART-TIME (PART) HEIFERS

	Full				Part			
Date	DM/ac[1]	DM[2] / BW	IVDMD[3] (%)	Protein (%)	DM/ac	DM / DW	IVDMD (%)	Protein (%)
11-9	4500	3.48	87.0	24.7	--	--	--	--
11-29	3938	1.60	86.5	23.4	2555	--	88.4	25.9
12-19	4645	2.84	87.5	23.3	3229	1.12	86.2	25.6
1-16	2379	1.36	85.6	23.3	2121	0.71	87.9	20.3
2-13	1236	1.00	86.7	21.5	2104	0.69	87.3	23.7
3-12	1543	0.97	86.9	23.8	1243	0.58	86.5	19.9
4-11	1768	0.81	81.7	18.0	1639	0.46	78.2	20.1
5-2	1863	0.64	74.1	15.4	948	0.22	68.4	18.4
5-21	1477	0.63	72.4	15.2	788	0.15	67.5	16.3

[1]Pounds of forage dry matter (DM) per acre.
[2]Pounds of forage dry matter (DM) per pound of animal body weight (BW).
[3]*in vitro* dry matter digestibility (IVDMD).

TABLE 2. DRY MATTER AND NUTRITIVE VALUE OF AVAILABLE FORAGE IN PADDOCK GRAZED BY HAY-SUPPLEMENT (HSUP) AND HAY-COTTONSEED MEAL (HCSM) HEIFERS AFTER REMOVAL FROM DRYLOTS

Date	DM/ac[1]	DM[2] / BW	IVDMD[3] (%)	Protein (%)
3-12	1061	1.18	82.2	19.4
3-28	823	0.89	81.9	17.9
4-11	904	0.96	84.9	18.4
4-25	1286	1.30	80.5	19.6
5-9	1713	1.67	74.9	20.7
5-30	1952	2.35	72.1	22.2
6-13	3184	3.63	65.6	19.2

[1]Pounds of forage dry matter (DM) per acre.
[2]Pounds of forage dry matter (DM) per pound of animal body weight (BW).
[3]*In vitro* dry matter digestibility.

At initiation of the trial, all heifers averaged 269 days of age and 480 lb in weight (Table 3). Age at puberty was lowest in the HSUP group and highest in the HCSM group ($P<.05$). However, two heifers in the PART group did not reach puberty before July 16. Heifer weight at puberty was greatest in the HCSM group ($P<.05$) and lowest in the PART group. Body condition score at puerty ($P<.001$) followed a similar trend among treatments as did weight at puerty. Differences in height and length of heifers at puberty due to treatments were not significant.

The percent of heifers reaching puberty and becoming pregnant during the test period are also shown in Table 3. Groups HSUP, HCSM, and FULL had 100 percent of the heifers to reach puberty during the trial; whereas, only 69 percent of the heifers in the PART group reached puberty during the same time period. Pregnancy rate was high and nearly identical for heifers in the HSUP and HCSM groups. The percent pregnancy of heifers in the FULL group was considerably less than anticipated. A closer examination of the average daily gain (ADG) of heifers in the FULL group revealed that the open heifers in that grop gained 31 percent less than the pregnant heifers (.79 *vs* .60) (Table 4). Therefore, the low ADG from these individuals was probably responsible for the low pregnancy rate. Further examination of FULL *vs* either HSUP or HCSM needs attention to ascertain whether these differences are due to weight gain or to differences in the nutritional components of the diet.

Table 4 shows heifer ADG differences as influenced by treatment group and period. Heifers in the HCSM and PART groups made compensating gains from March 12 to May 21 and again from May 21 to July 16. The PART heifers did not fully compensate, however, for their lack of gain during the November 9 to March 17 period. As a result, the heifers in the

TABLE 3. PHYSICAL TRAITS OF HEIFERS AT INITIATION OF THE TRIAL AND AT PUBERTY

	Initial Heifer status			Heifer status at puberty							Pregnant Heifer status	
Group	No.	Age (days)	Weight (lb)	No.	Percent	Age (days)	Weight (lb)	Body Score	Height (in)	Length (in)	No.	Percent
HSUP	14	272	481	14	100	376	644 ± 106	6.7	46.9 ± 2.2	44.9 ± 2.8	13	93
HCSM	13[1]	265	476	13	100	454	703 ± 95	7.0	48.6 ± 1.9	46.9 ± 2.5	12	92
Full	14	269	485	14	100	389	615 ± 95	6.2	47.4 ± 2.9	45.4 ± 2.2	9	64
Part	13[2]	271	476	9	69	409[†]	600 ± 73	5.5	47.9 ± 1.4	44.9 ± 2.7	7	54

[1]Heifer broke leg and was removed from study.
[2]Heifer injured back and was removed from study.
[†]Two heifers did not reach puberty during trial and data from them were not included in this table.

TABLE 4. AVERAGE DAILY GAIN OF HEIFERS BY PERIODS AS INFLUENCED BY TREATMENTS

	Average daily gain (lb)					
Group	11-9 to 3-12	3-12 to 5-21	5-21 to 7-16	11-9 to 7-16 (250 days)	7-16 to 9-8	11-9 to 9-8 (304 days)
HSUP	1.30	1.38	.93	1.24	.28	1.07
HCSM	.77	1.68	1.48	1.15	.38	1.01
Full	1.17	1.84	.71	1.15	.26	1.01
Part	.49	.79	1.01	.81	.34	.73

TABLE 5. PASTURE AND FEED COSTS PER HEIFER FROM HAY-SUPPLEMENT (HSUP), HAY-COTTONSEED MEAL (HCSM), FULL-TIME WINTER PASTURE (FULL), AND PART-TIME WINTER PASTURE (PART)

Group	Supplemental feed costs[1]	Small grain-ryegrass[2]	Clover-ryegrass[3]	Total feed-pasture costs	No. days	Cost/ day	ADG (lb)	Cost/ wt gain (lb)	Cost/ Pregnancy
HSUP	$91.40	--	$28.00	$119.40	250	$.48	1.34	.36	$128.39
HCSM	62.83	--	28.00	90.83	250	.36	1.25	.29	98.73
Full	--	$76.67	7.00	83.67	250	.33	1.25	.26	130.73
Part	36.73	15.80	7.00	59.53	250	.24	0.88	.27	110.24

[1]Supplemental feed costs used were as follows: Hay @ ($60/Ton); Milo @ ($130/Ton); Cottonseed meal @ ($200/Ton).

[2]Small grain-ryegrass (prepared seedbed) pasture costs included fertilizer (200-60-60), seed, land preparation, and planting for a total of $115/acre. Sod-seeded pasture cost estimates were $95.00/acre.

[3]Clover-ryegrass pasture costs included fertilizer (100-60-60), seed, and planting for a total of $70.00/acre.

PART groups gained less ($P<.001$) than the other three groups. This lack of full compensatory gain may have been due to: (1) the climate conditions, which were generally unfavorable for rapid forage growth in the spring, and/or (2) an unusually high incidence of internal parasites which is a common occurrence in producer herds wintered in dense animal populations. Daily gain at 250-days was nearly identical for the HSUP, HCSM, and FULL groups.

Table 5 presents feed and pasture cost comparisons during the trial. Costs which are not calculated in these figures, but which are an integral part and must be inclued in the replacement heifer costs are labor, capital costs, and interest on fixed and variable costs. Heifers in the HSUP group had the highest winter feed-pasture cost at $119.40 per heifer; whereas, heifers in the PART group had the lowest individual winter cost at $59.53 each. Heifers in the HCSM and FULL groups had intermediate costs of $90.83 and $83.67 per heifer, respectively.

The real comparative costs in raising replacement heifers are not the total feed-pasture cost, cost per day, nor the cost per pound of gain. Rather, it is the cost per heifer that became pregnant during a given breeding season. Heifers in the HCSM group from November 9 until March 12 and then allowed access to ryegrass-clover-bermudagrass from March 12 to July 16 had the lowest pasture-feed costs per pregnancy at $98.73. Thus, by combining hay and ryegrass-clover grazing, the higher costs of both supplemental feed and small grain-ryegrass pasture were supressed. Heifers from the PART group were intermediate at $110.24 per pregnant heifer; whereas, heifers from the HSUP and FULL groups had the highest costs per pregnancy at $128.39 and $130.73, respectively.

It was concluded that compensatory gains via programmed forage utilization schedules may be used to a biological and economical advantage in the development of replacement heifers. Furthermore, gains immediately preceding and during breeding may be more important than winter gains in terms of pregnancy rates and cost per pregnancy.

Marketing Options

PR-3955

Cattle Feedlot Decision Strategies Under Alternative Price Relationships

G. M. CLARY AND R. A. DIETRICH

Summary

This study developed decision models for cattle feeders relative to optimum strategies concerning feeder cattle placements, feeding, and marketing programs under existing and projected prices for fed slaughter cattle during 1971-75. Alternative futures trading strategies also were analyzed for use by cattle feeding management under variable price relationships existing for feeder cattle, major feed grains, and slaughter cattle during 1971-75.

Optimum decision models were developed in this study by focusing on the projection of net returns above variable costs. The models developed accurately projected profits or losses for nearly 80 percent of the feedlot data (lots) sampled. If strategies suggested by these models had been used by cattle feeding management, average net returns above variable costs for the lots studied would have increased from −$18.52 to $33.08 per head during 1972-75. The development of such decision models would have allowed cattle feeders to plan feeding programs prior to expenditures for feed and/or feeder cattle.

This study also revealed that when projected slaughter cattle prices were compared with beef cattle futures prices, cattle feeders could have increased their hedging efficiency. Losses incurred by cattle feeders during 1972-75 would generally have been minimized by using selective hedging strategies for the lot data sampled. Selective hedging strategies can provide price-risk protection and allow for feeding unhedged cattle during periods of anticipated fed slaughter cattle price increases.

Introduction

Prior to the volatile economic environment evident in 1973, price relationships for feedlot input items and fed cattle remained at levels insuring a profit for most cattle placed on feed. A series of events occurred during 1973-76 which resulted in economic disaster for the cattle feeding industry, as witnessed by losses of $100 or more per head for cattle placed in the feedlots studied during this period.

Some contributing factors to the cattle feeders' economic woes included a spiraling inflation and a temporary drop in real income, which made housewives more price conscious at the retail meat counter. Increases in beef prices led to a consumer boycott of beef and a presidential executive order for ceilings on beef prices which hampered normal marketings. Merchandizing problems arose at the retail level when consumers resisted over-fed-beef prices and tended to purchase lower priced non-fed beef.

In addition, feed grain prices moved up sharply during 1973-75, while the cattle numbers cycle approached a peak in the U.S. and other major beef producing countries. These factors resulted in sharply declining fed and non-fed cattle prices. The net result was that many cattle feeders incurred large financial losses from the fall of 1973 through 1977 with the exception of a short period during 1975. These large financial losses emphasized the importance of cattle feeders' decision-making processes. Losses incurred can be attributed to errors in purchasing, feeding, and marketing strategies under prevailing economic relationships, and to the misinterpretation of available data on which decisions were based.

Experimental Procedure

The primary source of data for this study was lot close-out data for 25 percent of the lots fed and closed out on a monthly basis from four selected feedlots in the Texas Panhandle during 1972-75. The four feedlots represented feedlot size groups and management levels existing in the Texas Panhandle cattle feeding industry during this period.

Data concerning feed costs and prices for feeder cattle and fed cattle were obtained from statistics published by the U.S. Department of Agriculture and from feedlot industry sources as required. Interest rates on borrowed funds were not available from feedlot close-out records, so interest was applied at the rates specified by banks for short term (less than one year) feeder cattle loans (7).

Standard frequency distributions and data categorized in tabular form were used to obtain a greater understanding of the type of cattle fed and marketed by selected feedlots, and the costs and prices associated with these cattle. General description data were developed relative to (1) proportion of total Texas placements represented, (2) placement and marketing patterns, (3) proportion of steers (heifers) fed, (4) weight of feeder and fed steers (heifers), (5) length of feeding period, (6) daily weight gain, and (7) feed conversion rates. Costs and prices analyzed included (1) laid-in costs of steers (heifers), (2)

slaughter steer (heifer) prices, (3) cost of rations fed and (4) total feed cost per pound of gain.

Multiple linear regression analysis was utilized to estimate net returns above variable costs under existing price relationships for selected feedlots (Model I) and to compare and evaluate the accuracy of projecting fed slaughter cattle price (Model II). Multiple regression also was used to develop a decision model estimating net returns above variable costs under projected fed slaughter cattle prices (Model III).

Results and Discussion

Three types of prediction models were developed to depict the 1971-75 price relationships for feeder cattle, feed grains, and slaughter cattle. Model I was designed to estimate net returns above variable costs for steers and heifers under existing price relationships from 1972-75 feedlot close-out data. This relationship was developed for both steers and heifers to allow for differences in basic feeding characteristics and performance. Selected variables were identified and found to be statistically significant in explaining the variation associated with changes in net returns for steers and heifers (Table 1).

The prediction accuracy of Model I was tested by comparing observed net returns from lot close-outs with values estimated by Model I. The steer and heifer equations predicted the 1972-75 profit and loss situations for 95 percent and 92 percent of the steer and heifer lot close-outs, respectively. Incorrect estimates can be attributed to extreme values in the data such as death losses, conversion ratios, or feeder-fed cattle price margins.

Model II projected fed slaughter steer and heifer prices using data available to cattle feeders and feedlot managers prior to placing feeder cattle on feed (Table 1). All data were on a quarterly basis and were lagged two time periods to represent the average feeding interval of approximately 180 days. All selected variables were statistically significant with respect to changes in projected slaughter steer and heifer prices. However, Model II was limited in its ability to precisely predict changes in slaughter steer and heifer prices during the period studied since the variables included in the equation explained only 39 percent of the variation in slaughter steer prices and only 44 percent of the variation in slaughter heifer prices.

Model III was designed to project net returns above variable costs for steers and heifers using those data available to cattle feeders when feeder cattle were placed on feed. Equations from Model I and projected fed slaughter steer and heifer prices from Model II were incorporated into Model III to estimate net returns above variable costs for use in optimum decision making relative to placing cattle on feed (Table 1).

Steer and heifer equations for Model III correctly projected a profit or loss for nearly 80 percent of the lots sampled. A systematic analysis of this type could lead to more profitable cattle feeding strategies. For example, if cattle had been placed on feed only when a profit was predicted, average net returns above variable costs, as represented by the lot data sampled, would have increased from −$18.52 per head to $33.08 per head or a net increase of $51.60 per head. Incorrect projections of net returns by Model III were primarily due to the inability of the variables in

TABLE 1. REGRESSION COEFFICIENTS FOR MODELS I, II AND III, FOUR SELECTED FEEDLOTS, TEXAS, 1972-75[a]

	Variables[b]											
Model	INT	LC	SP	CPH	DAYS	TG	EM	BS	RP	CSH	ESP	R^2
Model I-Steers	10.75 (1.47)	−685.36 (−63.74)**	1168.16 (70.13)**	−200.07 (−71.28)**	−1.28 (−35.09)**	0.45 (27.87)**						0.97
Model I-Heifers	−17.60 (−1.35)	−474.02 (−24.41)**	898.12 (25.88)**	−170.94 (−29.97)**	−1.17 (−17.55)	0.48 (14.25)**						0.89
Model II-Steers	−0.14 (−3.09)**						0.02 (4.06)**	0.07 (10.38)**	0.19 (14.04)**	−0.15 (−8.14)**		0.39
Model II-Heifers	−0.06 (0.95)						0.02 (5.88)**	0.05 (4.86)**	0.18 (11.03)**	−0.15 (−6.86)**		0.44
Model III-Steers	−33.44 (−0.98)	−608.67 (−17.88)**		−217.50 (−21.32)**	−1.49 (−12.97)**	0.54 (10.09)**					1239.38 (13.04)**	0.70
Model III-Heifer	12.58 (0.35)	−401.86 (−10.22)**		−159.71 (−13.52)**	−1.18 (−9.46)**	0.38 (7.47)**					730.29 (6.69)**	0.61

[a]The t-values of the estimated parameters are directly below each coefficient. ()* and ()** denote statistical significance at the .05 and .01 probability levels, respectively.

[b]INT = constant value intercept, dollars per head (Models I and III) and dollars per pound (Model II).
LC = laid-in costs of feeder steers, dollars per pound.
SP = fed slaughter steer (heifer) price, dollars per pound.
CPH = daily feedlot cost per head, dollars per head.
DAYS = length of feeding period, days per head.
TG = total gain, pounds per head.
EM = expected monthly feedlot marketings, thousand head.
BS = commercial U.S. beef production, previous 3 months, billion pounds.
RP = monthly U.S. retail price of USDA Choice beef, dolalrs per pound.
CSH = cold storage holdings, U.S. red meat, by months, billion pounds.
ESP = estimated fed slaughter price, dollars per pound (Model II).

Model II to precisely predict sudden increases or decreases in slaughter cattle prices at the time cattle were placed on feed.

Three alternative hedging strategies were applied to all lots of cattle sampled. Average net returns above variable costs which would have been realized under each strategy are shown in Table 2. Hedging all lots of cattle would have decreased average net returns per head by $53 in 1971, $42 in 1972, and more than $68 from January to June during 1975. Under periods of decreasing slaughter cattle prices, such as during 1973-74, futures contracts generally may be bought back for less than their initial selling price. Losses would have been decreased by about $22 per head in 1973 and $56 per head in 1974 by hedging all cattle placed on feed compared to a "no hedge" position.

The selective hedging strategy would have further minimized losses incurred by cattle feeders during 1973-74 (Table 3). This strategy was developed to alleviate indiscriminate hedging of all lots of cattle without regard for future price expectations. Prior to placing cattle on feed, a comparison was made between the projected slaughter cattle price from Model II and the local beef cattle futures price. If the projected slaughter cattle price was greater than the current local futures price, no hedge was initiated such as in 1971-72 and most of 1975. If the projected slaughter cattle price was less than the current local futures price, contracts nearest the anticipated fed cattle marketing date were sold to hedge the specific lot of cattle placed on feed. If such a strategy had been applied to all lots sampled for 1973 and 1974, losses incurred by cattle feeders would have decreased nearly $15 and $9 per head, respectively, as compared to hedging all lots of cattle fed.

Selective hedging provides for price risk protection only when it appears necessary and still allows flexibility for capturing cash price increases. Results of the selective hedging strategy revealed that few lots would have realized greater net returns above variable costs by not following such a strategy.

Future use of decision models may affect many sectors of the livestock and meat industry. Employment of decision models by cattle feeders to more accurately predict profits and losses can remove much of the uncertainty associated with decision making in cattle feeding. Decision models, such as those presented in this study, not only provide cattle feeders with a vehicle to more nearly optimize management decisions in cattle feeding, but may also have a significant effect upon decision making by cow/calf producers, feed grain producers and grain companies, financial institutions, slaughtering firms, and meat wholesalers and retailers.

TABLE 2. HEDGING STRATEGIES APPLIED TO ALL LOTS OF CATTLE FED, FOUR TEXAS PANHANDLE FEEDLOTS, 1971-75

Year	Strategy		
	No hedge	Hedge all lots	Selective hedge
	$/Head		
1971[a]	31.27	−22.18	b
1972	18.59	−23.33	b
1973	−61.35	−39.80	−24.99
1974	−91.20	−35.36	−26.73
1975[c]	62.62	−6.02	54.19
Average[d]	−18.55	−33.17	2.32

[a]Includes July - December placements.
[b]No hedges initiated during this period for lots sampled.
[c]Includes January - June placements.
[d]Weighted average.

TABLE 3. HEDGING STRATEGIES APPLIED TO LOTS OF CATTLE FED WITH PROFIT PROJECTED BY MODEL III, FOUR TEXAS PANHANDLE FEEDLOTS, 1971-75

Year	Strategy		
	No hedge	Hedge all lots	Selective hedge
	$/Head		
1971[a]	30.89	−22.51	30.89
1972	18.88	−12.79	18.88
1973	56.85	−41.28	55.30
1974	40.14	32.60	50.31
1975[b]	68.73	4.82	58.18
Average[c]	33.08	−14.56	31.73

[a]Includes July - December placements.
[b]Includes January - June placements.
[d]Weighted average.

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PR-3956

Retail Meat Operations in Texas

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Summary

A survey of firms retailing meat in the Dallas-Ft. Worth, Houston, and Lubbock Standard Metropolitan Statistical Areas (SMSAs) was conducted by personal interview in 1979. This publication focuses on the relative volumes of product handled, procurement methods, and distribution channels, by type of retailer.

Beef accounted for two-thirds to three-fourths of the physical volume of meat purchases by retailers during the period studied. Substantial variability existed in the market channels among cities depending on the availability of local meat suppliers.

Retail grocers continue to be the most significant group within the retail marketing system, even though meat markets have demonstrated a resurgence in some areas. The trend of increased "away from home" eating has reduced the retail grocer's share of meat sales. Dallas-Ft. Worth, Houston, and Lubbock hotels, restaurants, and institutions (HRIs) handled 19 percent, 18 percent, and 30 percent, respectively, of the total beef in the SMSA area studied compared to 16 percent for a similar study in the St. Louis area. Increasing costs, especially labor costs, will continue to have a substantial impact on the structure of the retail meat industry.

Introduction

Meat marketing has undergone significant change in the last century. This study is part of a regional study to describe the current status of meat marketing channels. Since World War II, the cattle slaughtering industry has shifted from nearby large consumption centers to the concentrated cattle feeding areas in the Great Plains and the Western Cornbelt (4). Many of these structural changes were facilitated by technological innovations in packaging, refrigeration, warehousing, transportation, and communication. The general trend has been toward more direct marketing and simplification of distribution channels.

The development of the present marketing system was based on, among other things, the use of low cost energy for refrigeration, transportation and packaging. It is likely that in another decade, continued high energy costs will have significant impacts on production and distribution within the meat industry.

This study characterizes the structure of the red meat retailing industry in three diverse metropolitan areas of Texas (3). Data and information presented include variability in the volumes of meat handled, the type of product mix, and services offered by retailers within and among the cities surveyed. In addition, the marketing channels which beef, pork and luncheon meat follow to reach consumers are identified for these same areas.

The principal retail outlets for red meat are grocery stores, meat markets and dining establishments. Dining establishments include hotels, restaurants and institutional eating establishments, referred to as the "HRI trade."

Changes at the consumer level as well as other economic and social forces often result in structural changes within the retail food industry (4). Such adjustments are precipitated by changes in population, personal income, shopping habits, and consumption patterns in addition to technological and organizational innovations.

Innovations are evident in processing, preservation, packaging and distribution of red meat (3). Retailer owned centralized warehouses and meat fabrication centers remain prominent throughout the retail industry. However, they may be losing popularity as boxed meat programs become more economically efficient.

Developments in the production, slaughtering, and distribution of red meat significantly influenced retailing in the United States, as well as Texas (4). The advent of large concentrated commercial feedlot operations has led to the specialization and concentration of slaughtering establishments near these feeding areas. Increasing costs, especially for energy and labor, along with the development of vacuum packaging, have prompted slaughtering firms to install carcass fabrication facilities to accommodate shipments of primal and subprimal cuts directly to wholesalers and retailers. Such developments have altered the procurement and processing policies of meat retailers. This study provides a picture of how the retail meat industry appears in three different cities in an effort to understand how these developments have modified the movement of red meat in various forms (degrees of fabrication or processing) through marketing channels to meat retailers in Texas.

Procedure

Data for this study were obtained through personal interviews with owners, managers, and purchasing agents of firms retailing red meat in the Dallas-Ft. Worth, Houston, and Lubbock SMSAs of Texas for 1979. An initial statistical sample of firms was randomly selected by United States Department of Agriculture (USDA) statisticians as part of a regional study being conducted by the Economic Research Service, USDA. The sample was drawn from a population which combined firms listed in the telephone yellow pages and firms registered with the Texas State Comptrollers Office as handling food and paying sales taxes. Each SMSA was treated independently in the sampling of firms selling meat to the final consumer (restaurants, retail grocers, meat markets, and institutions).

Results

Meat markets averaged nearly as much volume of beef as grocery chain stores, whereas, independent grocers had substantially lower volumes (Table 1). Considerable variability was evident in volumes of meats handled by members of the HRI trade. More consistent with expectations was the fact that average volumes of pork and luncheon meat handled by meat markets was considerably less than by chain grocery stores. In addition, even though convenience stores accounted for a rather substantial share of total store numbers, they accounted for a relatively small share of total meat sales.

Red meat consumption patterns in Texas were found to differ somewhat from those in the United States (U.S.) Beef accounted for 55.7 percent of the per capita red meat consumption in the U.S. in 1979 (7). Survey results indicated that beef accounted for two-thirds to three-quarters of the red meat handled by retailers in Texas during the same period (Table 2).

Even though firms were classified somewhat differently, data indicated that HRIs in the SMSAs studied handled from 5 percent to 17 percent more of the total beef sold within the SMSA study area than did Los Angeles County HRIs in 1956 (5). Dallas-Ft. Worth and Houston HRIs handled 19 percent and 18 percent of the total beef, respectively, compared to 16 percent in the St. Louis area (1). Comparisons for pork and luncheon meats were not readily available due to differences in product classifications.

Steer and heifer beef, primarily fed beef, represented almost 40 percent of the meat handled by retailers in 1974 (4). In the current study, fed beef, represented by USDA Prime, Choice and Good categories, accounted for approximately 60 to 70 percent of all meat handled by similar types of retailers.

General restaurants purchased 39 to 45 percent of their beef as ground beef or beef for grinding (manufacturing beef) while fast food restaurants purchased 70 percent of their total beef in these forms. At the point of sale, ground beef often includes a certain

TABLE 1. AVERAGE MEAT PURCHASES PER WEEK PER RETAIL OUTLET, BY TYPE OF RETAILER AND KIND OF MEAT, SELECTED SMSA, TEXAS, 1979

Type of retailer and SMSA	Beef	Pork	Luncheon Meats
	--------pounds per week---------		
Chain retail grocery			
Dallas-Ft. Worth	6,995	2,030	1,140
Houston	7,033	3,243	1,173
Lubbock	5,600	1,772	919
Independent retail grocery			
Dallas-Ft. Worth	1,182	402	178
Houston	1,081	757	168
Lubbock	879	853	385
Convenience stores[1]			
Dallas-Ft. Worth	4	10	49
Houston	8	19	16
Lubbock[2]	21	3	149
Meat markets			
Dallas-Ft. Worth	6,131	1,268	359
Houston	5,309	1,388	182
Lubbock	5,250	1,091	320
General restaurants[1]			
Dallas-Ft. Worth	768	176	70
Houston	308	119	26
Lubbock	660	50	7
Fast food restaurant[1]			
Dallas-Ft. Worth	368	52	6
Houston	659	45	20
Lubbock	388	37	76
Cafeterias			
Dallas-Ft. Worth	359	76	15
Houston	[3]	[3]	[3]
Lubbock	640	212	5
Institutions			
Dallas-Ft. Worth	98	5	36
Houston	72	13	20
Lubbock	171	21	8

[1]Includes chains and independents

[2]Includes only independents, no data were reported by chains.

[3]None reported by respondents interviewed.

TABLE 2. COMPARISON OF VOLUMES OF MEAT HANDLED BY TYPE OF MEAT AND RETAILER, SELECTED SMSA, TEXAS, 1979

Type of product and retailer	Dallas-Ft. Worth	Houston	Lubbock
	----------percent of volume----------		
Type of product sold			
Beef	74.2	65.9	72.9
Pork	17.6	25.3	17.6
Luncheon meats	8.2	8.8	9.5
Total	100.0	100.0	100.0
Type of outlet			
Beef			
Retail grocer	41.4[1]	71.2	52.3
Meat market	39.5[1]	10.5	18.1
Restaurant	18.0	17.7	27.4
Institution	1.1	0.6	2.2
Beef total	100.0	100.0	100.0
Pork			
Retail grocer	51.4[1]	86.7	73.3
Meat market	34.4[1]	7.1	15.8
Restaurant	14.0	5.9	10.3
Institution	0.2	0.3	0.6
Pork total	100.0	100.0	100.0
Luncheon meat			
Retail grocer	66.7[1]	90.5	78.0
Meat market	20.8[1]	2.7	8.5
Restaurant	8.7	5.6	12.8
Institution	3.8	1.2	0.7
Luncheon meat total	100.0	100.0	100.0

[1]Percentage for retail grocers may be low and high for meat markets due to errors in estimating the population of stores sampled and/or properly weighting survey data. Data were weighted by sample sizes.

proportion of fed beef in addition to manufacturing beef.

Pork accounted for 17 to 25 percent of all red meat handled by retailers in the three areas studied. Retail grocers and meat markets handled more than 85 percent of all pork purchased by retailers. Pork was generally purchased as fresh cuts, sausage, bacon and hams. Fresh cuts, especially whole loins for fabrication into pork chops, accounted for nearly 50 percent of all pork handled by retail grocers surveyed.

Luncheon meat products generally accounted for less than 10 percent of all red meat sold. Nevertheless, such products play a significant role in meat marketing as they utilize many pork and beef by-products from the fabrication process.

Transportation continues to play a significant role in the form of meat puchases and the channels through which meat flows to reach retailers. A 1975 study states that nearly 16 percent of fed beef was purchased as boxed by Texas retailers (4). Substantial increases in boxed beef purchases were evident especially by grocery stores in areas further removed from concentrated cattle slaughter areas as Houston (Table 3). Although pork carcass purchases accounted for 16 percent of the pork obtained by Houston meat markets, almost all pork was purchased as boxed subprimals by retailers in the SMSA areas.

Packers, packer sales offices, and wholesalers each supplied about one-third of the red meat purchased by retailers in the Dallas-Ft. Worth area. Retailers in Houston purchased nearly one-half of their red meat supplies from wholesalers with much of the remainder being supplied by company-owned warehouses or commissaries. Lubbock retailers, being close to many beef packers, purchased over 75 percent of their red meat supplies directly from packers.

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TABLE 3. PROPORTION OF BEEF PURCHASED AS BOXED BEEF BY RETAIL GROCERY STORES, MEAT MARKETS, AND GENERAL RESTAURANTS, SELECTED SMSA, TEXAS, 1979

	Dallas-Ft. Worth	Houston	Lubbock
	----------percentage of volume ----------		
Grocery Stores			
Chain	18.1	34.9	56.7
Independent	23.9	68.5	97.9
Meat Markets	3.0	23.8	1.7
General Restaurants			
Chain	28.5	12.5	96.3
Independent	34.3	54.5	58.4

Land, Water and Fuel Usage

PR-3957

Energy Evaluation of Grain Sorghum Processing

L. M. SCHAKE, F. M. BYERS AND K. L. BULL

Most feed grains respond favorably to several processing techniques resulting in less grain required per unit of liveweight gain. However, some processing techniques require considerable energy in the form of electricity, natural gas and/or diesel. Therefore, current energy budgets were established to compare five grain sorghum processing alternatives for commercial cattle feedlots with one time capacities of 5,000 or 20,000 head.

Energy budgets were developed for dry-processed; steam-flaked; oxygen-limited reconstitution; early harvested-ground and ensiled in trench silos; and early harvested acid-treated grain sorghum. Data for energy requirements and costs of operation were obtained through industry sources during the first quarter of 1980. Consumption of electricity, natural gas and diesel was determined for each size of feedlot for processing grain sorghum by each of the five techniques. Costs were fixed at $.05 per kwh for electricity, $2.00 per mcf for natural gas and $.21 per liter for diesel. Grain requirements were estimated assuming a 90 percent feedlot occupancy with 1,180 kg of grain required to accomplish 204 kg of net gain per head and a feedlot turnover rate of 2.12 times per year.

Energy cost per ton of dry grain for the 20,000 head feedlot was $.08, 2.96, .20, .11 and .33, respectively for dry-processed, steam-flaked, reconstituted, early harvest-ground-ensiled and early harvest-acid treated grains. Comparable values for a 5,000 head feedlot were $.08, 4.25, .23, .13 and .46. Approximately one-half of the total processing cost per ton for steam flaking at the feedlot was represented by fuel cost. Other systems required less than 5 percent of total processing cost per ton.

Energy recovered as empty body energy per unit of energy added above dry processing was 50.5 fold for reconstitution, 36.8 for early harvest-ground-ensiled, 4.2 for early harvest-acid treated and 3.6 for steam-flaked.

PR-3958

Feedlot Manure Harvesting: Cost and Energy Consumption

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Feedlot manure harvesting operations were computer-simulated to identify system combinations that provide least cost and minimum energy consumption. This compuer modeling study was conducted for four feedlot sizes (5,000; 10,000; 25,000; and 50,000 head one time capacity) and three manure hauling distances (1, 5 and 10 miles one-way).

Four manure collection and hauling systems were assumed: System A — Collect manure with elevating scraper and stack in pens, load trucks from pens using wheel loaer, haul to stockpile or land; System B — Wheel loader for manure collection and stacking in pens; load trucks with wheel loader and haul to stockpile or land; System C — Collect with elevating scraper and haul directly to stockpile; System D — Collect with wheel loader, load trucks directly, and haul to stockpile or land.

Each system was analyzed using mathematical models based on finite source cyclic queueing theory to determine the least-cost and least-fuel combination. Equipment capacities assumed were elevating scraper — 11 cu yd capacity; wheel loader — 1.25, 2.00, and 4.00 cu yd capacity; and hauling or spreader truck — 5, 10, 15 35 cu yd capacity. Owning and operating costs (1980 prices) were estimated using standard procedures for the construction industry.

Hourly fuel consumption data were obtained from equipment manufacturers. Other assumptions were feedlot manure collection rate (2 tons/hd/yr) and manure density (1350 lbs/cu yd). Machine cycle times and production rates for pen cleaning, loading and hauling were estimated from previous time-motion investigations by the authors. From the above input data, annual equipment operating times were calculated from computer models. Annual machine useage was then used to determine hourly owning and operating cost and cost per ton for each system. In all cases, System D yielded the lowest fuel consumption, which ranged from 0.03 to 0.09 gal/ton-

mile. Fuel useage was independent of feedlot size but decreased with increased haul distance. System D was also the least cost system in almost all instances.

The least-cost system would result in 40 to 60 percent higher fuel consumption for small feedlots (5,000 head), but would require only 0 to 8 percent higher fuel consumption for 25,000 and 50,000 head feedlots. By contrast, for a given feedlot size and haul distance combination, a least-fuel system would cost 30 to 250 percent more per ton than a least-cost system for feedlots with 5,000 to 25,000 head. This was caused by greater energy efficiency generally achieved with larger machinery, which had higher fixed costs and lower operating time per year. However, there was less than 12 percent cost difference for 50,000 head feedlots between the least-cost and least-fuel systems.

As expected, manure handling costs varied with feedlot size and haul distance. A ten-fold increase in feedlot size (5,000 hd to 50,000 hd) produced 42 to 64 percent reduction in least-cost manure handling. Similarly, a ten-fold increase in one-way haul distance (1 to 10 miles) caused a 70 to 180 percent increase in predicted manure handling costs. Predicted costs of manure handling for a 25,000 head feedlot with 5-mile manure hauling distance were as follows: System A — $1.71/ton; System B — $1.51/ton; System C — $2.49/ton; and System D — $1.36/ton. The latter cost increased to $2.04 for a 10 mile haul distance. System A (scraper/stack/loader/truck) cost only 8 to 26 percent more than System D for 25,000 to 50,000 head feedlots with 5 to 10 mile haul distance. System B (loader/stack/loader/truck) cost only 4 to 13 percent more than System D for these conditions. System C was competitive only for the 0.5 mile haul distance.

In most cases studied, the predicted least cost system would entail the smallest wheel loaders (1.25 cu yds) and largest trucks (35 cu yds), contrary to conventional feedlot practice. This combination reduces idle time of wheel loaders and reduces unit cost and energy consumption for hauling.

PR-3959

Harvesting Feedlot Manure for Biogas or Combustion Fuel

J. M. Sweeten, D. J. Undersander, D. L. Reddell, and A. Higgins

Inorganic solids (ash) in feedlot manure reduces the concentration of organic solids and nutrients, therefore lowering the manure value. Excessive ash also contributes to mechanical problems in manure handling and reuse systems. Fresh cattle manure normally contains 15 percent ash on a dry weight basis. Decomposition and admixing with soil often increases the ash content from 30 to 75 percent of dry matter.

An experimental program was conducted at a 50,000 head cattle feedlot in Swisher County, Texas, to determine variations in feedlot manure quality (ash content, heating value, and sulfur content) as a function of depth within the manure pack. A second objective was to determine the quality of feedlot manure that could be harvested with an elevating scraper. The sampling study involved one feedpen (35,000 sq. ft. area) in which 210 heifers had been fed for 152 days.

Loose dry surface manure and damp manure on the concrete feedbunk apron had the highest quality in terms of utilization potential, but constituted a small fraction of the harvestable manure. These products were similar, containing 22 percent ash, 2.9 percent nitrogen, and 7,010 BTU/lb heat content on a dry-matter basis. The sulfur content (0.77 percent) was similar to the other manure sampled. The moisture content averaged 36 percent for feedbunk apron manure and 14 pecent for loose surface manure.

The manure pack was sampled at three strata: A — loose surface manure and compacted layer; B — damp, unconsolidated, intermediate layer; C — granular manure/soil interface layer. There were highly significant differences in ash and heat contents among the three manure strata. The manure/soil interface layer (stratum C) contained much greater ash (73.5 percent) and much lower heat content (1,910 BTU/lb) on a dry basis than manure in the overlying layers. By comparison, strata A and B had ash contents of 27.5 and 32.6 percent and heat contents of 6410 and 5850 BTU/lb, respectively. Moisture and sulfur content also showed statistically significant differences attributable to manure strata. The middle manure layer (stratum B) contained almost twice as much moisture as manure strata A or C. Sulfur concentration was lowest in the manure/soil interface layer (stratum C).

There were no significant differences among the three strata sampled either in terms of sulfur content when expresed as lbs sulfur/million BTU's or heat content when expressed on a dry, ash-free basis. There were no statistical differences among any of the parameters attributable to location within the feedpen. There was a strong negative correlation between heat content and ash content (R^2 = 0.996). In other words, ash and moisture diluted the heating value of the manure. On a dry ash-free basis, the heat content for all manure strata averaged 8,300 BTU/lb (range of 4,945 to 9,263 BTU/lb) but manure strata A and B averaged only 8800 BTU/lb.

The chemical quality of manure harvested with an elevating scraper was compared with manure left on the feedlot surface after harvesting. The ash content was significantly lower and the heat content significantly higher in the harvested manure compared to the manure/soil interface layer left on the

surface. Nitrogen content was also higher for the collected layer (2.6 percent vs. 1.0 percent d.b.), however this difference was not statistically significant. There was no significant difference between the collected and uncollected layers in terms of moisture content or sulfur content. The majority of the manure pack could be collected with an elevating scraper to yield a fuel feedstock with 30 percent ash and a heat of combustion of 6200 BTU/lb on a dry basis, which is comparable to a lower grade lignite.

PR-3960

Artificial Lighting for Cattle Feedlots

C. C. Cernik, L. M. Schake,
F. M. Byers and R. M. McDonald

Summary

Four feedlot lighting techniques for steers were evaluated in a fall/winter feeding experiment in North-eastern New Mexico. The control steers exhibited more desirable average daily gain, feed efficiency and cost per kg of gain by as much as 5.7 percent over the predawn/postdusk, midnight and continuous lighting treatments. Nonsignificant increases in eating and standing of predawn/postdusk treatment steers was observed at 0600 hrs. with less eating observed at 1200 hrs. compared to the other treatments. Steers in midnight and continuous light treatments had increased eating activity at 2400 hrs. compared to the control and predawn/postdusk treatments. Variable cost for lighting per kg of gain was 0.53 mills for the predawn/postdusk and midnight treatments and 1.16 mills for the continuous treatment. These data indicated that steers in open pen feedlots did not respond to supplemental lighting during the fall and winter seasons.

Introduction

Performance of feedlot cattle is most often measured by feed efficiency and average daily gain. The genetic makeup of each animal combined with the environment in which it lives determines performance. Modifying the environment to allow expression of the animal's genetic potential is one alternative to approach optimum performance. Environment of feedlot cattle includes factors such as nutrition, management, and seasonal factors related to pen conditions such as wind, humidity, temperature and light. Season of the year has been found to influnce feed intake, average daily gain, and feed efficiency of cattle in open pen feedlots (2). Day length may be modified through artificial lighting. Supplemental lighting as a managerial tool in improving the efficiency of feedlot cattle has been widely applied in the Southwest, but rising energy costs have forced producers to reconsider the use of artificial lighting in their feedlots. Therefore, a field trial was established to evaluate four lighting alternatives in a commercial feedlot.

Procedure

Four lighting treatments were established including a control with natural lighting plus supplemental lighting at predawn/postdusk, midnight and continuous night lighting. Lighting for the predawn/postdusk and midnight treatments was limited to 16 hrs per day. The difference between 16 hrs. and the natural day length represented the hours of supplemental light divided equally before dawn and after dusk, or before and after midnight. The continuous lighting treatment had supplemental lighting from dusk to dawn. A sunrise and sunset schedule[a] was utilized to determine day length during the fall and winter of 1980-1981 at American Cattle Feeders, Inc. near Clovis, New Mexico where this experiment was conducted.

The control, predawn/postdusk and midnight treatments each consisted of 275 steers. The continuous treatment consisted of 276 steers. Each herd was placed in a uniform open pen with feedbunks in a North-South orientation located on the West side of each pen. Each of the four pens was located on the Southwestern corner of four different alleys in the feedlot. One 400 watt high-pressure sodium vapor floodlight was positioned on a 9.1 m pole at the Southwestern corner of each lighted pen (Figure 1). The floodlights were focused on the area between the feedbunk and the water trough. Timers were used to control the floodlights and were adjusted for varying day length. A computerized simulation was utilized to predict the level of illumination throughout the pens in each treatment.[b]

On September 28 and 29, 1980, 2000 mixed crossbred steers were weighed upon arrival at the feedlot, placed in holding pens and fed hay plus a starter ration. The steers were then sorted according to U.S.D.A. frame size (8) on September 29. Eleven hundred and one medium-frame steers were randomly assigned to four lots, one for each lighting treatment. On September 29 and 30, the steers were reweighed and processed. Processing consisted of branding, vaccinations and injections with Tramisol and Vitamins A, D and E. The steers were implanted with Synovex-S; horns tipped, and tails bobbed, dipped in a 2% Prolate solution, and placed in their respective pens. The steers were reimplanted with Synovex-S approximately 60 days later.

[a]Cannon Air Force Base, Clovis, New Mexico

[b]Floodlighting Analysis Program EL503. 1980. Electrical Design Dept., Brown & Root, Inc., Houston, Texas.

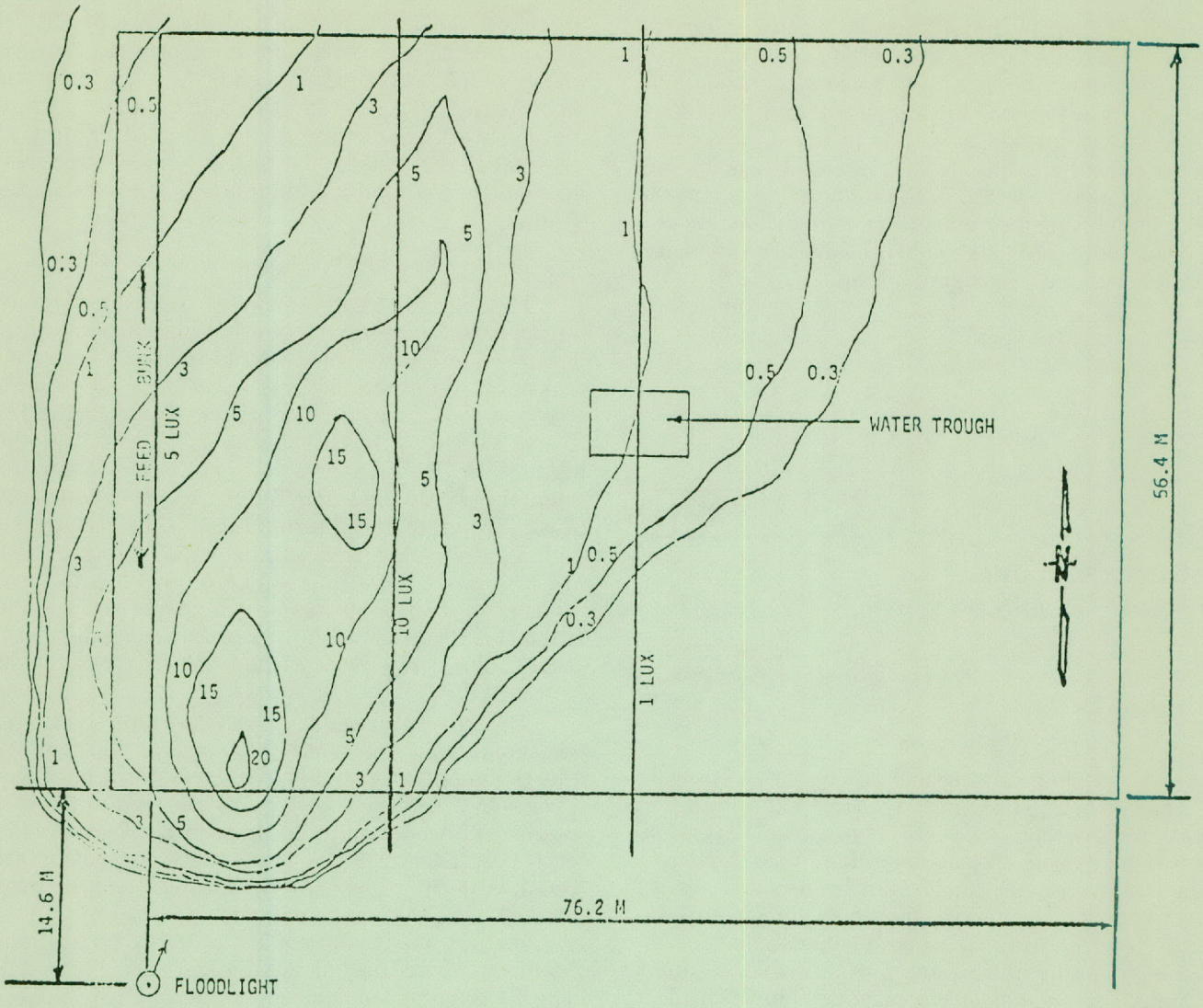

Figure 1. Isolux curves of lighted pens.

All steers were fed on the same ration sequence. An analysis of the rations fed is presented in Table 1. The steers were fed a starting ration for 7 days followed by two intermediate rations each fed for 7 days. The finishing ration was fed for approximately 123 days (range of 119 to 125 days) depending on the day each lot was sold. Bunks were observed each morning to establish daily feed assignments with the daily feed assignment divided in two portions. Each steer was provided with an average of 15.6 m^2 of pen area and 205 mm of linear bunk space.

Steer behavior was observed and recorded over twenty weeks. The number of steers in each pen that were observed eating, drinking, and standing was recorded at 0600, 1200, 1800 and 2400 hrs. These observation times were selected because they were major and minor feeding periods identified in research on steer feeding habits during the winter in Arizona (5). Observation of cattle activities required approximately 10 minutes per treatment. A one-way analysis of variance was utilized to evaluate behavior of the steers by treatment. Steer performance was obtained from the feedlot data, and carcass data was obtained from the packing plant. Energy and economic budgets were established from current installations and energy costs in the Clovis, New Mexico area, assuming a one time feedlot capacity of 25,000 head.

Results and Discussion

Simulated light intensities in each of the lighted pens is presented in Figure 1. The light intensity along the feedbunk was an average of five lux. Along a North-South line approximately 24.4 m and 45.7 m into the pen, the light intensity was ten lux and one lux, respectively. By comparison, bright moonlight has an intensity of approximately 0.1 lux (1). Each treatment received an average of 10.51 hrs. of natural daylight per day during this experiment. Predawn/postdusk and midnight treatments received an average of 5.49 hrs. of supplemental light per day and the continuous treatment received 13.49 hrs. of supplemental light per day.

TABLE 1. COMPOSITION OF FEED FED TO EXPERIMENTAL STEERS[a]

Item	Ration			
	Starter	Intermediate	Intermediate	Finisher
Net energy m, Mcal/kg	1.76	1.87	2.00	2.13
Net energy p, Mcal/kg	1.04	1.15	1.27	1.36
Crude protein, %	12.17	12.38	12.83	12.41
Crude fiber, %	15.19	12.03	8.49	7.29
Calcium, %	0.78	0.74	0.96	0.83
Phosphorous, %	0.29	0.30	0.33	0.33

[a]All values are expressed on a dry matter basis.

Average daily gain and feed efficiency were not improved by any of the three lighting techniques compared to the control (Table 2). Summer trials conducted in Michigan (6) and California (3) reported similar results. A Texas study (4) compared mercury vapor and high pressure sodium floodlights and reported no differences in peformance of steers. In all feedlot performance criteria measured, the controls exhibited more desirable responses by as much as 5.7 percent over the three lighting treatments (Table 2). Dressing percent was similar for the control, predawn/postdusk, midnight and continuous treatments. However, percent USDA Low Choice (7) and above carcasses favored the midnight and continuous lighting treatments at 58 and 46 percent, respectively vs. 29 and 31 percent for controls and predawn/postdusk lighting treatments.

The means of the 20 week behavior data are given in Table 3. No significant difference was indicated because of wide variation in cattle activity within treatment. However, a shift in behavior was seen in each of the lighting treatments compared to the

TABLE 2. STEER PERFORMANCE

Item	Lighting treatment			
	Control	Predawn/ Postdusk	Midnight	Continuous
Number of steers	275	275	275	276
Average initial weight, kg	321.85	327.43	327.76	329.81
Days on feed	147	146	141	140
Average daily gain, kg	1.28	1.26	1.26	1.25
Feed intake per day (dry matter), kg	9.43	9.50	9.63	9.62
Feed efficiency (dry matter)	7.36	7.55	7.65	7.78
Cost of gain, $/kg[a]	1.51	1.52	1.56	1.57
Average sale weight (includes 4% shrink), kg	509.84	510.75	505.31	503.49
Number of deaths	1	0	3	0
Dressing percent	63.59	62.92	63.40	62.86
U.S.D.A. Low Choice carcasses or above, %	29	31	58	46

[a]Does not include cost of lighting or interest cost on feed fed or cattle.

TABLE 3. MEANS OF BEHAVIORAL OBSERVATIONS, NUMBER OF STEERS

Activity	Time(hrs.)	Lighting treatment				
		Control	Predawn/ Postdusk	Midnight	Continuous	SEM
Eating	0600	7	14	7	5	1.98
	1200	37	28	37	38	4.05
	1800	61	61	57	56	2.33
	2400	25	23	30	29	2.70
Drinking	0600	7	2	2	1	.30
	1200	7	6	5	6	.46
	1800	7	8	7	6	.51
	2400	3	4	3	3	.20
Standing	0600	15	22	17	18	2.56
	1200	59	44	59	56	3.52
	1800	186	184	193	192	2.20
	2400	44	34	31	40	3.00

[a]Observation dates were October 10, 17, 24, 31; November 7, 14, 21; December 9, 28; January 5, 12, 19, 26; February 2, 9, 16. The minimum number of observations per treatment for each activity at 0600, 1200, 1800 and 2400 hrs. was 14, 16, 15 and 10 times, respectively.

control. Predawn/postdusk steers were observed to eat and stand more at 0600 hrs. compared to all other treatment steers. The predawn/postdusk steers ate less frequently at 1200 hrs. in the midnight and continuous treatments compared to the control and predawn/postdusk treatments.

Lighting budgets (Tables 4 and 5) established the fixed and variable cost to uniformly light a 25,000 head feedlot. Variable cost of lighting per kg of gain was 0.53 mill for the predawn/postdusk and midnight treatments and 1.16 mills for the continuous treatment. Total fixed cost were 4.01 mills per kg of gain for the predawn/postdusk and midnight treatments and 4.04 mills per kg of gain for the continuous treatment.

These data indicated that steers in open pen feedlots in Northeastern New Mexico did not respond to supplemental lighting during the fall and winter seasons.

TABLE 4. COST OF INSTALLING LIGHTS IN A 25,000 HEAD FEEDLOT

	Lighting treatment		
Item	Predawn/ Postdusk	Midnight	Continuous
Initial investment, $[a]	108,000	108,000	108,000
Loan repayment, $/yr.[b]	34,536	34,536	34,536
Fixed cost, mills/kg[c] of gain	4.01	4.01	4.04

[a]Assuming 72 floodlights were required to uniformly light a 25,000 head feedlot at a cost of $1500 per light.

[b]Reprsents annual payment of a 5 year loan of $108,000 with 18% interest. Interest computed annually on remaining balance.

[c]Feedlot operating at 75% capacity. Cattle gains are those observed in this experiment.

TABLE 5. ENERGY BUDGET FOR LIGHTING A 25,000 HEAD FEEDLOT[a]

	Lighting treatment		
Item	Predawn/ Postdusk	Midnight	Continuous
Supplemental light hrs./yr.[b]	144,300	144,300	345,520
Energy consumption kwh/yr.[c]	72,150	72,150	177,760
Energy cost, $/yr.[d]	3,608	3,608	8,890
Maintenance and repair, $/yr.[e]	1,000	1,000	1,000
Total variable cost, $/yr.	4,608	4,608	9,890
Variable cost per kg of gain, mills	0.53	0.53	1.16

[a]Assumes 72 floodlights are required to uniformly light a 25,000 head feedlot at the intensity of the treatments utilized in this experiment.

[b]Based on average number of hours of supplemental light supplied to each treatment during this fall/winter trial. Actual hours would differ with natural day length.

[c]Assuming an efficiency of 80% for a 400 watt high pressure sodium vapor floodlight consuming 0.5 kwh of electricity per hour.

[d]Assume electrical cost of $0.05/kwh.

[e]Estimated value.

[f]Assume 25,000 head feedlot operating at 75% capacity. Cattle grains are those observed in this experiment.

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Role of Beef in Human Nutrition and Health

PR-3961

Cholesterol Content of Raw and Cooked Beef Muscles with Different Amounts of Marbling

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Summary

The relationships of marbling level (eight levels from "Moderately Abundant" to "Practically Devoid") and cooking to the cholesterol content of beef longissimus (loin) steaks, trimmed of all external fat, was studied. For raw steaks, only steaks with "Practically Devoid" marbling had significantly less cholesterol than did steaks with the other seven marbling scores; no significant differences were found between any of the other seven marbling groups. However, when steaks were cooked to an internal temperature of 140°F or 167°F, no significant differences were found in cholesterol content among any of the eight marbling groups. For raw as well as cooked steaks, marbling score and fat content were significantly correlated with cholesterol content, but the highest correlation coefficient was 0.43 — explaining only 18 percent of the variation in cholesterol content. Due to loss of moisture, cooking increased the amount of cholesterol per gram of cooked steak by 22 to 48 percent when cooked to an internal temperature of 140°F and by 38 to 65 percent when cooked to 167°F. However, the total amount of cholesterol contained in each steak does not increase due to cooking. Cooking only reduces the weight of each steak, making the amount of cholesterol per gram of that steak higher. The cook drip contained only a small proportion (0.3 to 2.6 percent) of the cholesterol present in the raw steaks. Based on the results of this study, it appears that consumers need not be concerned about the amount of marbling in beef in relation to the cholesterol content of the steaks they eat.

Introduction

Consumers presently are very conscious of the nutritive content of foods as this is related to their health. In this connection, dietary cholesterol level has become an important issue since the publication of "Dietary Goals for the United States" by the Senate Select Committee on Nutrition and Human Needs. That publication recommended a reduction in cholesterol consumption as a means of preventing heart diseases. However, there are scientists who believe that at least some of the recommended diet modifications for the prevention of coronary heart diseases are based on assumptions which are not yet adequately tested.

Values reported in the literature for the cholesterol content of beef vary widely. This study was undertaken to determine the effects of marbling level and cooking on the cholesterol content of beef longissimus steaks.

Materials and Methods

Eighty beef carcasses were selected to have "Moderately Abundant", "Slightly Abundant", "Moderate", "Modest", "Small", "Slight", "Traces" or "Practically Devoid" marbling level (10 carcasses for each marbling level). Two steaks (1.25-inches thick) were cut from the longissimus muscle of the loin of each carcass and trimmed of all external fat. One of the steaks was analyzed raw (10 per marbling group) and the other one was analyzed after cooking to an internal temperature of either 140°F or 167°F (5 per marbling/cooking group). Steaks were cooked from the frozen state in a preheated oven at 350°F.

Total fat content was determined (2) and the cholesterol content was determined (4) after saponification of the extracted lipids (2).

Data were evaluated by analysis of variance, the Student-Newman-Keuls' test, correlation procedure, and the t-test for paired comparison.

Results and Discussion

Data on cholesterol contents of raw and cooked

TABLE 1. MEAN CHOLESTEROL VALUES (mg/100g) FOR RAW AND COOKED BEEF LONGISSIMUS STEAKS HAVING DIFFERENT AMOUNTS OF MARBLING[a]

Marbling score	Raw steaks	Cooked steaks	
		Cooked to 140°F	Cooked to 167°F
Moderately abundant	64.74 a	86.42 a	89.55 a
Slightly abundant	62.48 a	87.36 a	88.34 a
Moderate	61.43 a	87.13 a	90.01 a
Modest	65.88 a	80.18 a	92.20 a
Small	64.00 a	78.30 a	90.79 a
Slight	59.95 a	81.28 a	86.27 a
Traces	60.06 a	81.35 a	85.72 a
Practically devoid	51.77 b	76.67 a	85.57 a

[a]Means in a column which are not followed by the same letter are significantly different ($P<0.05$)

steaks are presented in Table 1. For raw steaks, no significant differences in cholesterol content were found among steaks with different amounts of marbling except that steaks with "Practically Devoid" marbling contained significantly less cholesterol than did steaks with any of the other seven marbling scores; no significant differences were found between steaks from any of the other seven marbling groups. When steaks were cooked, however, there were no significant differences between steaks of any of the eight marbling groups regardless of whether the steaks were cooked to an internal temperature of 140°F or 167°F. Thus, at the time steaks are eaten (cooked), there is no difference in the amount of cholesterol consumed regardless of the amount of marbling that the steaks may have had.

Correlation analysis (Table 2) revealed that, for raw as well as cooked steaks, marbling score or fat content was significantly correlated with cholesterol content except for the non-significant correlation between marbling score and cholesterol content for steaks cooked to 167°F. In no case, however, was the correlation coefficient between marbling score or fat content and cholesterol content greater than 0.43 — explaining only 18 percent of the variation in cholesterol content.

The cholesterol values shown in Table 1 for the uncooked beef longissimus muscle, i.e., 51.77 to 65.88 mg/100 g, are higher than the values reported by some researchers for the same muscle — 36 to 46 mg/100g (5) and 46 to 57 mg/100g (3) lower than the values reported by others, i.e., 78.16 mg/100g (b) and similar to the values in two other reports, i.e., 53.4 to 60.0 mg/100g (7) and 65 mg/100g (1).

Cooking increased the percentage cholesterol content of the cooked steaks, as evident in Table 1, primarily due to loss of moisture during cooking. The increase ranged from 22 to 48 percent when cooked to an internal temperature of 140°F and from 38 to 65 percent when cooked to 167°F (data not shown in tabular form). This compares with other research (1) in which there was a 40 percent increase in cholesterol content upon cooking lean beef trimmed of separable fat. The drippings collected during cooking contained only a small percentage (0.3 to 2.6 percent) of the cholesterol that was present in the steaks initially (data not presented in tabular form).

It should be pointed out that the total amount of cholesterol contained in each steak does not increase due to cooking. Cooking only reduces the weight of a steak, making the amount of cholesterol per gram of that steak higher. Cooking also increases the content (per gram of cooked weight) of other components of a steak such as protein.

In conclusion, the results of this study suggest that consumers need not be concerned about the amount of marbling in beef relative to its cholesterol content. The finding that uncooked steaks with "Practically Devoid" marbling had less cholesterol than did uncooked steaks with any of the other seven marbling score is of very little practical significance since the incidence of beef with that little marbling is very low. Of greater significance was the finding of no significant differences in the cholesterol content of cooked steaks due to differences in marbling.

TABLE 2. CORRELATION COEFFICIENTS AMONG EXPERIMENTAL VARIABLES

Variables	Raw steaks (n = 80)	Cooked steaks: Cooked to 140°F (n = 40)	Cooked steaks: Cooked to 167°F (n = 40)
Marbling score vs. cholesterol content	0.35**	0.43**	0.29^{ns}
Fat content vs. cholesterol content	0.39***	0.41*	0.32*
Moisture content vs. cholesterol content	−0.39***	−0.50**	−0.44**
Marbling score vs. fat content	0.81***	0.79***	0.78***
Marbling score vs. moisture content	−0.80***	−0.74***	−0.66***
Fat content vs. moisture content	−0.95***	−0.92***	−0.91***

***P<0.001
**P<0.01
*P<0.05
^{ns}Not significant, P>0.05

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PR-3962

Improving the Microbiological Quality of Variety Meats

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Summary

Complete microbiological assays were made of livers, kidneys and hearts (1) soon after slaughter, (2) after storage for 1, 3 or 5 days at 35 to 37°F, (3) after temperature abuse of 6 or 12 hr at 86°F, (4) after frozen storage for 4 days at −4 F and (5) after defrosting of frozen product for 24 or 48 hr at 77°F. If variety meats were promptly and properly refrigerated soon after slaughter, no major increases in microbial counts occurred during five days of storage at 35 to 37°F. Freezing arrested microbial growth but did not destroy microbes that were present on variety meats at the time of freezing. Major increases in microbial count (as much as $\log_{10}$ of 1.38 in 6 hr and 3.08 in 12 hr) occurred when variety meats were subjected to temperature abuse at 86°F. Defrosting of livers and kidneys for 24 or 48 hr at 77°F resulted in very large increases in microbbiological counts; counts were between 100 million and 1 billion per 0.16 in^2 after 48 hr of defrosting. The initial microbial flora of variety meats consisted primarily of coryneform bacteria and *Micrococcus* species. Although storage for five days at 35-37°F did not cause major increases in microbial counts, the number of samples on which *Pseudomonas* species constituted 25 percent or more of the microbial flora more than tripled. Microbial flora of variety meats before and after freezing was often dominated by coryneform bacteria and *Micrococcus* species.

Introduction

The microbiological quality of variety meats is important to the United States meat industry since large quantitites of these products, especially livers, are shipped in the frozen state to Europe for subsequent retail sale or for manufacturing purposes. Previous reports (1, 2, 3) have shown that the microbiological quality of variety meats often is inferior because of poor sanitation during handling and inadequate chilling and/or freezing prior to shipment. The present study deals with effects of refrigeration, freezing and thawing on microbial counts and flora of livers, hearts and kidneys.

Experimental Procedures

Livers, kidneys, and hearts were obtained from several meat packing plants in Texas. Samples were transported to the laboratory in oxygen-permeable polyvinyl chloride (PVC) film, covered with ice. Samples stored in the "chilled" state were kept in PVC film at 35 to 37°F. Samples to be stored frozen were wrapped in aluminum foil and frozen at −29°F; before sampling, they were thawed overnight at 36°F.

For the experiments in which livers and kidneys were frozen (1) immediately after slaughtering and dressing and (2) after storage for 6 or 12 hr at 86°F, organs were taken from animals that were processed at the Texas A&M University Meats Laboratory under identical conditions over a period of a few hours. In the experiments on the effect of defrosting on the microbial flora of livers and kidneys, commercially processed organs were used. In these tests, livers, two per box, were wrapped individually in unsealed polyethylene film. Kidneys were placed in polyethylene-lined 10-lb. boxes. When samples were subjected to various treatments (storage time, before and after freezing), each sample was cut with a sterile knife into as many parts as were required for the various treatments.

Sampling was conducted by removing a 1.55 sq. in. piece of tissue (.08 in. thick) from the surface (usually from 1-3 sites) of the organs with a sterile scalpel. Each sample was plaed in 100 ml sterile 0.1 percent peptone in a Stomacher bag and macerated for 1 min in a Stomacher- 400. Appropriate dilutions were plated on prepoured plates of tryptic soy agar (TSA) by the spread-plate method and the plates were then incubated for 48 hr at 77°F. Colonies were picked from countable plates, placed on TSA slants and incubated for 48 hr at 77°F. Identity of microbes was determined by biochemical test and identification schemes (4).

Results and Discussion

Clean and sanitary handling of variety meats and rapid chilling (within 30 minutes after removal on the slaughter-dressing floor) resulted in variety meats which usually had microbial counts of less than 10,000 ($\log_{10}$ of 4.00 or lower) per 0.16 square inch of surface area after as long as 5 days storage at 35°F (Table 1). Thus, if variety meats are promptly and properly refrigerated, no major increases in microbial count are likely to occur during a 5-day storage period at normal refrigeration temperatures.

Although it is well-known that freezing can cause sublethal injury and death to many microbial species in foods, freezing of livers, kidneys and hearts did not cause significant changes in microbial

TABLE 1. EFFECT OF REFRIGERATED STORAGE AT 35-37°F ON AEROBIC PLATE COUNTS OF VARIETY MEATS

Variety meat	Aerobic plate count ($\log_{10}$/0.16 in^2) Day 0	Day 5
Liver	2.48[a]	2.60
Kidney	2.72	3.34
Heart	2.07	3.25

[a]An aerobic plate count of 2.00 would mean that there are 100 microbes on each 0.16 square inch of meat surface; an aerobic plate count of 3.00 would correspond to 1,000 microbes per 0.16 square inch, *et cetera*.

TABLE 2. EFFECT OF FROZEN STORAGE AT −4°F ON AEROBIC PLATE COUNTS OF VARIETY MEATS

Variety meat	Aerobic plate count (log_{10}/0.16 in^2)	
	Before freezing	After frozen storage for 4 days
Liver	2.19	2.62
Kidney	2.64	2.97
Heart	3.15	2.47

count (Table 2). These results reveal that freezing can be expected to arrest growth and proliferation of microorganisms on variety meats as long as the product remains frozen, but freezing will not destroy microbes that are present on the organs at the time of freezing.

When livers and kidneys were subjected to temperature abuse (at 86°F ambient temperature for 6 or 12 hours) prior to freezing, major increases in microbial counts occurred (Table 3). Leaving variety meats on the slaughter-dressing floor during a workshift, or holding such products in an unrefrigerated storage area for periods of 6 or 12 hours prior to boxing and either chilling or freezing can greatly increase the microbial count of organ meats.

Defrosting of beef livers and kidneys for 24 or 48 hours at 77°F (Table 4) can lead to very large increases in microbial counts. Regardless of whether such an occurrence was accidental (e.g., the failure of a freezing unit during frozen storage) or intentional (e.g., use of the meat that required it to be thawed), the end-result could be serious indeed — counts were between 100 million and 1 billion per 0.16 square inch after 48 hours. Variety meats with microbial counts of that magnitude are likely to be spoiled and not usable.

Classification of microbes present on variety meats revealed that the initial microbial flora of livers, kidneys and hearts consisted primarily of coryneform bacteria and *Micrococcus* species; *Pseudomonas* species occurred, but less frequently. Although storage for 5

TABLE 3. EFFECT OF TEMPERATURE ABUSE AND SUBSEQUENT FREEZING ON MICROBIAL COUNTS OF LIVERS AND KIDNEYS

Sequence	Treatment	Aerobic plate count (log_{10}/0.16 in^2)	
		Liver	Kidney
I	After 30 min at 86°F	2.64	3.38
	After 1 month at −4°F	2.78	3.20
II	Upon removal from the animal	2.08	3.28
	After 6 hr at 86°F	3.15	4.66
	After 1 month at −4°F	3.84	3.76
III	Upon removal from the animal	2.79	3.45
	After 12 hr at 86°F	5.78	6.53
	After 1 month at −4°F	5.72	5.75

TABLE 4. EFFECT OF DEFROSTING/STORAGE TIME (AT 77°F) ON MICROBIAL COUNTS OF COMMERCIALLY FROZEN LIVERS AND KIDNEYS

Variety meat	Aerobic plate count (log_{10}/0.16 in^2)		
	0 hours	24 hours	48 hours
Liver	5.00	5.46	8.76
Kidney	5.85	6.11	8.67

days at 35°F did not cause major increases in microbial counts, the number of samples on which the *Pseudomonas* species constituted 25 percent or more of the microbial flora more than tripled. Extended "chilled" storage of variety meats in oxygen-permeable PVC film showed that quality deterioration and ultimate spoilage was frequently caused by *Pseudomonas* species. These bacteria are commonly responsible for quality losses and spoilage of raw meats, poultry and fish stored under refrigeration exposed to the air or packaged in films with high permeability to oxygen.

Results of these studies should be of interest to meat packers who wish to sell variety meats in the dometic (U.S.) trade (not always frozen) and/or to meat packers who freeze variety meats for subsequent transport-distribution to foreign markets. Good sanitary procedures during slaughtering/dressing and subsequent handling of variety meats result in a low initial bacterial count. Rapid chilling and/or freezing retards microbial growth; maintenance of cold (for unfrozen product) and frozen (for previously frozen product) conditions also retards microbial growth.

Long shelf-life of these products demands good sanitary procedures during slaughter-dressing and handling of the variety meats and prompt and proper refrigeration and/or freezing.

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Impact of Beef Activities within Environment

PR-3963

Integrated Management of Wintering Blackbirds at South Texas Feedlots

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A two-year study was designed to investigate the utilization of South Texas feedlots as daily foraging sites by overwintering blackbirds. Temporal and spatial feedlot utilization patterns, associated economic impacts, and relative effectiveness of bird population management techniques were evaluated. Thirteen species of birds were involved in the overall depredation. The brown-headed cowbird, red-winged and Brewer's blackbird, common grackle, and European starling were the major species present. Together they numbered from 50,000 to 200,000 birds at a single feedlot daily during the peak season from December through February.

The diets of all species appeared to consist entirely of feed grains and feed protein supplement, two expensive components of cattle rations. Cowbirds fed mostly from the feed troughs, while starlings and redwings fed extensively from both feed troughs and outside the troughs in spilled and spent rations. Brewer's blackbirds and grackles, along with the less important species present, fed mostly on spilled and spent rations outside the feed troughs.

At normal feeding rates, a mixed population of 100,000 birds might consume as much as 1,000kg (2200lbs) of grain and protein supplement per day. If only 50 percent of the feed were obtained from the feed troughs, daily feed loss could amount to $80 per day (at $150/ton), or nearly $2,500 per month. In addition, although not examined directly in this study, contamination of feed could reduce livestock feeding rates thus adding to the total depredation value by increasing overall costs of feeding. Similarly, avian transmission of disease, such as coccidiosis, could further add to the depredation value by increasing overall costs of feedlot operation.

Among the several bird population management tools evaluated (which included Avitrol, Starlicide, biosonic distress calls, propane cannons, noise and whistle bombs, sticky repellents, and traps), a combination of strategically placed and timed, elevated, swivel-mount propane cannons and periodic use of noise and whistle bombs, along with high levels of feedlot sanitation limiting the availability of rations to only the feed troughs, proved to be the most effective in reducing bird population activity. A detailed analysis of the extent of effectiveness and effect on overall economics of the bird depredation impact currently is underway.

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