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Comparison of Lines and Line Crosses for Economically Important Traits in Swine[1]

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Crossbreeding is used extensively in the production of slaughter hogs in the United States. It is estimated that approximately 85-90 percent of all slaughter hogs in the United States are of crossbred origin. Crossbreeding yields heterosis (depending on the traits and breeds involved) and permits breeders to combine the desirable characteristics of different breeds into the crossbred individual. Only few experimental results have been reported in this area for feedlot and carcass traits.

This study was undertaken to determine the magnitude of the advantage or disadvantage of the performance of line crosses as compared to purebred lines for various economically important traits. Three purebred lines and four line crosses from the Oklahoma swine breeding project were used.

Materials and Methods

The data included 1700 litters (7520 individual pig records) from the Duroc (OK8), Beltsville No. 1 (OK9), and Hampshire (OK14) lines of breeding and four specific crosses of these lines (Table 1) farrowed during the 23 seasons from 1954 fall through 1965 fall. Data for line 8—9$\times$14 (purebred dam) were only available from 1954 fall through 1958 spring, so data for line 14 $\times$ 8 — 9 (crossbred dam) for only these eight seasons were used to compare the performance of purebred dams to crossbred dams.

Pig weights represented the average weight for the pigs within a particular litter. All pigs were given access to creep at three weeks and were self-fed during the postweaning period. The average daily gain from weaning to market weight represented postweaning average daily gain. The ratio of units of feed consumed to units of gain produced

Table 1: Breeding Structure for the Seven Lines of Breeding Used in This Study.

Line	No. Litters	Breed Composition of: Sire	Dam	Litter
OK8	222	Duroc	Duroc	Duroc
OK9	195	Belts. No. 1	Belts. No. 1	Belts. No. 1
OK14	445	Hamp.	Hamp.	Hamp.
89	223	Duroc	Belts. No. 1	Duroc x Belts. No. 1
98	195	Belts. No. 1	Duroc	Belts. No. 1 x Duroc
14x8-9	331	Hamp.	Crossbred	Hamp. x Duroc-Belts.
8-9x14	89	Crossbred	Hamp.	Duroc-Belts. x Hamp.

[1] Department of Animal Science in cooperation with the Regional Swine Breeding Laboratory, AHRD, ARS, U.S.D.A.

was used as the measure of feed efficiency. Feed records were based on pen averages. Carcass length was obtained on the cold carcass and represented the distance from the forward edge of the first rib to the anterior edge of the aitch bone. Carcass backfat thickness was measured at the first rib, last rib, and last lumbar vertebra on each side of the carcass and the average of the six measurements was recorded. Loin eye area was the area of the *longissimus dorsi* muscle measured between the tenth and eleventh ribs.

All lines were not represented in all seasons; therefore, all analyses were done on a within line basis. Least squares procedures were used to adjust the preweaning traits for season, age of dam, number of pigs farrowed, and number of pigs weaned. Postweaning traits were adjusted for season, sex, and management system. All preweaning traits are reported on a second litter equivalent (1.5 years) basis. Since small numbers of litters were present in various age classifications for lines 8, 9, and 14 × 8 — 9, line 14 constants were used to adjust lines 8 and 9 for age of dam, and a multicross control line maintained at Ft. Reno was used to adjust line 14 × 8 — 9 for age of dam.

All models were constructed under the assumption that no interactions existed among the effects and that all errors were normally and independently distributed about a mean of zero and had a common variance σ^2. The standard errors of the mean differences were calculated under the assumption the means were independent.

Results and Discussion

Two-Line Crosses vs. Purebreds:

The performance of two-line crosses and parental lines is summarized in Table 2. For these specific line crosses, purebred dams with crossbred litters farrowed approximately one less live pig per litter than when their litters were purebred. Minnesota workers also obtained smaller litters among backcross litters and Ohio data revealed 1.1 fewer live pigs at birth for Berkshire-Duroc crosses compared to purebred Durocs. The failure to obtain an increase in litter size for the two-line cross may have been due to the lack of genetic diversity between lines 0K8 and 0K9 for this trait or it may have been unique for these lines. There was no difference in the number of pigs born dead which indicated that fewer total pigs were farrowed per litter in two-line cross litters. This may also indicate that there was more early embryonic death loss or a smaller number of eggs fertilized for purebred dams mated to boars of a different breed.

Crossbred pigs from straightbred dams were, on the average, heavier at birth than straightbred pigs. However, litter birth weights were slightly heavier for litters containing straightbred pigs. Previous work at this station indicated that litter size accounted for 67 percent of the variation in litter birth weight; therefore, the smaller litter size for the two-line cross could account for the decreased litter birth weight.

Table 2: Performance of Two-Line Crosses and Parental Purebreds.

Trait	Crossbred Avg. (89 & 98)	Purebred Avg. (8 & 9)	Difference Crossbred-Purebred	Standard Error
PREWEANING TRAITS:				
Number litters	418	417		
Live pigs farrowed/litter	9.2	10.2	— 1.0	0.02
Pigs born dead/litter	0.32	0.32	0.0	0.08
Pig birth weight, lb.	3.09	2.82	0.27	0.06
Litter birth weight, lb.	28.4	28.8	— .4	0.7
Pigs weaned/litter	7.3	7.1	0.2	0.2
Survival rate, percent	79.9	67.2	12.7	1.9
Pig 56-day weight, lb.	43.7	42.2	1.5	1.1
Litter 56-day weight, lb.	318.8	299.9	18.9	9.2
POSTWEANING TRAITS:				
Number pigs	1777	1936		
Avg. daily gain, lb.	1.67	1.58	0.09	0.01
Lb. feed/lb. gain	3.43	3.43	0.00	0.02
Carcass length, in.	29.8	29.4	0.4	0.1
Carcass backfat, in.	1.56	1.57	— .01	0.02
Loin area, sq. in.	3.73	3.60	0.13	0.04

Approximately a 13 percent increase in survival rate was obtained for two-line cross litters compared to the average of the parental purebreds, and as a result they weaned 0.2 pigs more per litter. This slight increase in litter size at weaning was non-significant and was smaller than results reported in most other studies. Undoubtedly, the decreased litter size at farrowing was a contributing factor. Part of what was measured as an increase in survival rate may have actually been due to the smaller litter size for the two-line crosses.

Crossbred pigs were heavier than straightbred pigs both for pig 56-day weight and litter 56-day weight. Crossing two purebred lines increased pig 56-day weight approximately 12 percent (4.8 lb.) and litter 56-day weight approximately 6 percent (18.9 lb.). The increases for litter 56-day weight in the two-line cross was expected since increases were obtained for number weaned and pig 56-day weight.

Two-line cross pigs gained 0.09 lb. per day faster than the average of the purebred pigs. This study revealed no difference in the feed required per lb. of gain for crossbred pigs compared to purebred pigs. Two-line cross pigs exceeded the average of the parental purebred pigs by 0.4 in. in carcass length. No significance was found between crossbred and straightbred pigs for carcass backfat thickness. Two-line cross pigs averaged 0.13 sq. in. larger loin eye area than the purebred parental lines.

Three-Line Cross vs. Purebred Lines:

The performance of line 14 × 8 — 9 (crossbred dam) and the average of the three purebred lines is summarized in Table 3. Crossbred sows farrowed 0.8 more live pigs per litter and weaned 1.0 more pigs per litter

Table 3: Comparison of the Three-Line Cross With the Three Purebred Lines Making Up the Cross.

Trait	3-Line Cross Avg.	Purebred Avg.	Difference 3-Line Cross —Purebred	Standard Error
PREWEANING TRAITS:				
Number litters	331	862		
Live pigs farrowed/litter	10.7	9.9	0.8	0.2
Pigs born dead/litter	0.21	0.32	— .11	0.08
Pig birth weight, lb.	3.05	2.89	0.16	0.05
Litter birth weight, lb.	32.6	28.6	4.0	0.6
Pigs weaned/litter	7.9	6.9	1.0	0.2
Survival rate, percent	73.9	67.7	6.2	1.9
Pig 56-day weight, lb.	42.0	41.3	0.7	0.7
Litter 56-day weight, lb.	331.9	284.8	47.1	7.9
POSTWEANING TRAITS:				
Number pigs	1807	3477		
Avg. daily gain, lb.	1.46	1.51	— .05	0.01
Lb. feed/lb. gain	3.45	3.40	0.05	0.02
Carcass length, in.	29.9	29.4	0.5	0.1
Carcass backfat, in.	1.50	1.52	— .02	0.01
Loin area, sq. in.	3.54	3.69	— .15	0.04

than the average of the three purebred lines. With the relatively large purebred average obtained, this would indicate a definite advantage for the crossbred sow for litter size. Slightly fewer pigs were born dead in litters from crossbred sows. Pig and litter birth weights favored the crossbred pigs by 0.10 lb. and 4.0 lb., respectively. The increased litter birth weight of the crossbred pigs was expected since increases were obtained for both litter size and pig birth weight. The larger pig birth weight may account for the decreased death loss at farrowing of the crossbred pigs. Survival rate increased approximately 6 percent when crossbreeding was used. The larger litter size at weaning and a larger pig 56-day weight (1.2 lb.) undoubtedly contributed to the 47 lb. increase in litter 56-day weight of line 14 × 8 — 9.

Although line 14 × 8 — 9 was definitely superior for preweaning traits, purebred pigs appeared to be slightly superior for postweaning traits. Purebred pigs gained 0.05 lb. per day faster, required 0.05 lb. feed less per lb. of gain, and had 0.15 sq. in. more loin eye area than crossbred pigs. Crossbred pigs had 0.5 in. longer carcasses and slightly less carcass backfat.

Crossbred Sow vs. Purebred Sow:

To critically evaluate the advantage of the crossbred dam, the performance for line 14 × 8 — 9 (crossbred dam mated to Hampshire boar) was compared to the performance of line 8 — 9 × 14 (crossbred boar used on Hampshire dams). Although many of the differences in performance between these two crosses were small; of the 8 preweaning traits studied (Table 4), line 14 × 8 — 9 was superior to line 8 — 9 × 14 for seven of these traits. Litter size was in favor of the crossbred sow by approximately one pig at farrowing and 0.4 pig at weaning. Crossbred sows farrowed heavier pigs and heavier litters than purebred dams. Litter 56-day weight favored the crossbred sow by approximately 41 lb. A slight, but non-significant, advantage for survival rate (1.6 percent) was noted for straightbred dams but this may have been due to their smaller litter size.

Line 8 — 9 × 14 pigs gained 0.02 lb. per day faster during the postweaning period and their loin eye area was 0.10 sq. in. larger (Table 4). Line 14 × 8 — 9 pigs had 0.06 in. less backfat than 8 — 9 × 14 pigs.

Although the magnitude of the observed differences were small, the crossbred sow was consistently superior to the purebred sow when the breed composition of the pigs was the same.

SUMMARY

The performance of lines and line crosses was studied using 1700 litters (7520 individual pig records) from the Duroc (OK8), Beltsville No. 1 (OK9), and Hampshire (OK14) lines of breeding and four specific crosses of these lines farrowed during the 23 seasons from 1954 fall through 1965 fall. All analyses were done on a within line basis using least squares procedures.

Purebred dams with crossbred litters farrowed smaller litters (—10 percent) than purebred dams with purebred litters, but their crossbred litters were larger at weaning. Crossbred pigs were 3 percent heavier at birth and 12 percent heavier at weaning. Crossbred litters were not larger at birth but were larger at 56 days. Crossbred pigs gained faster and had longer carcasses with a larger loin eye area.

Table 4: Comparison of Three-Line Crosses.

Trait	Line 14x8-9	Line 8-9x14	Difference	Standard Error
PREWEANING TRAITS:				
Number litters	141	89		
Live pigs farrowed/litter	10.4	9.4	1.0	0.4
Pigs born dead/litter	0.29	0.42	— .13	0.16
Pig birth weight, lb.	3.06	2.98	0.08	0.06
Litter birth weight, lb.	31.8	28.0	3.8	1.1
Pigs weaned/litter	7.8	7.4	0.4	0.4
Survival rate, percent	74.8	76.4	— 1.6	3.3
Pig 56-day weight, lb.	41.6	38.4	3.2	0.9
Litter 56-day weight, lb.	324.9	283.8	41.1	13.6
POSTWEANING TRAITS:				
Number pigs	705	459		
Avg. daily gain, lb.	1.37	1.39	— .02	0.01
Carcass length, in.	29.6	29.5	0.1	0.1
Carcass backfat, in.	1.55	1.61	— .06	0.02
Loin area, sq. in.	3.30	3.40	— .10	0.07

Crossbred dams with three-line cross litters were superior to the average of the three purebred lines for 10 of the 13 traits studied. Significant differences were obtained for 8 of the 10 traits. These traits were live pigs farrowed per litter (0.8 pig), birth weight (0.10 lb.), litter birth weight (4.0 lb.), pigs weaned per litter (1.0 pig), survival rate (6.2 percent), litter 56-day weight (47.1 lb.), carcass length (0.5 in.) and carcass backfat thickness (-.02). Purebred pigs were superior for average daily gain (0.05 lb./day), feed efficiency (0.05 lb. feed/lb. gain) and loin eye area (0.15 sq. in.).

Crossbred dams with crossbred pigs were definitely superior to purebred dams with crossbred pigs for 5 of the 12 traits studied. These traits were number of live pigs farrowed per litter (1.0 pig), pig birth weight (0.13 lb.), litter birth weight (3.8 lb.), litter 56-day weight (41.1 lb.) and carcass backfat thickness (—.06 in.). Crossbred pigs from purebred dams were significantly superior to crossbred pigs from crossbred dams only for average daily gain.

Pork Can Be Processed Before Chilling

R. L. Henrickson

It is well to have meat animal production efficiency but unless slaughtering and processing are also efficiently accomplished, the whole industry is placed in jeopardy. The actual reversal of physical movement of product in its trip through a plant is wasteful. These plant inefficiencies could be called "thermal backtracking", since many cuts are chilled and reheated.

When it is considered that more than 70 percent (ham, picnic, belly, butt, and fat) of the carcass will be heated to a temperature in excess of 137°F (58.3°C), it seems desirable to critically examine the existing processing method. Particularly when the original body temperature of the hot carcass is approximately 102°F (38.8°C) and is chilled down to a temperature of 35°F (1.7°C) for cutting. Chilling, reheating, and rechilling tons of pork (10,736,000,000 lbs. Federally Inspected) annually is not only costly, but adds time and opportunity for fat oxidation and microbial contamination to occur. Under present processing procedures it takes 12 to 18 hours of refrigeration to reduce the carcass temperature below a harmful bacteria level. The carcass is then cut and moved back through the bacterial incubation zone for smoking and cooking.

It is well established that hot muscle has excellent binding properties and is desirable in sausage manufacture. In addition, there appears little reason to chill fat before it is rendered for lard.

Cutting "hot pork carcasses" could help the processor by reducing inventory costs. Part of the inventory would remain in the pen and reduce the need for expensive refrigerated storage. The amount of chilling space would be reduced since fat, bone and skin would not be refrigerated. Therefore, plant operation would become more efficient and output increased. However, before continuous processing of warm carcasses can be termed commercially feasible, it will be necessary to provide an end product of desired quality. New equipment must be designed, constructed, and developed. Existing equipment and plant facilities will need modification. Labor requirements and large volume testing of the new concept will be necessary before the process will be adopted by the food industry.

This work was initiated to compare the quality of pork products processed to a finished form prior to initial chill with products processed after an initial chill.

Materials and Methods

Eighty barrows of similar breeding, age, and weight (91 Kg) when slaughtered were used in these studies. The animals were slaughtered according to the methods and practices currently used in the industry. Following bleeding, scalding, dehairing and eviscerating, the carcasses were split and washed prior to assignment to the alternate processing treatments. Pre-chill processing involved removal of the wholesale parts and processing the cuts within 30 minutes after slaughter. The warm cuts were trimmed free of excess fat and chilled in a blast freezer at —62°C until the center temperature reached 10°C, then tempered in a room at 1.7°C. Post-chill processing involved a 24 hour chill period at 1.7°C prior to any cutting or processing. Processing of the chilled cuts was the same as for the pre-chill pieces.

The hams were removed from the hot carcass (internal temperature 1.7°C), defatted, injected with brine to 110% of green weight, boned, and inserted into fibrous casing, placed directly into forming molds, heated, and smoked. Chilling the hot ham was accomplished at —62°C, until the internal temperature reached 10°C, followed by tempering to a temperature of 1.7°C. Samples for detailed physical, chemical, histological, and microbiological studies were taken at appropriate points in the processing.

Results and Discussion

The processing of pork products to a finished form prior to initial chilling appears to have many feasible applications to present fabrication techniques. Adaptation of all or part of the process by industry will, however, likely be slow since some change in equipment and plant layout will be needed. While the pliable nature of the warm meat will facilitate processing at some points in the fabrication process, it will likely require equipment modifications at other areas of the line.

Cutting the warm carcass seems to be easier than for a chilled carcass. The ease of fat and bone removal are facilitated. Preliminary evidence indicated that brine will penetrate warm muscle more rapidly than chilled muscle.

The yield of conventional wholesale cuts as a result of pre-chill processing was not significantly affected by the new method. Slight difference in the size or shape of the piece was noted primarily due to the position of the carcass as it was cut. The effect of pre-chill processing on the yield and loss of ham is presented in Table 1. The differences in yield were not significant. In every case the variation could be accounted for by the way in which the ham was removed from the carcass. In some hams more flank muscle was left while in others more fat was removed. The greater total loss in the post-chill ham was also reflected in the amount of total moisture remaining in the ham after complete processing, Table 1.

The Warner-Bratzler shear value as a measure for tenderness was made using ¾ inch diameter cores of the semimembraneous and longissimus dorsi muscles. The difference in tenderness between the processing methods was non-significant. Weiner 1964 found rapid processed ham more tender than the controls. However, the methods of processing the ham were different.

Pre-chilled cured ham contained more salt than the post-chill cured ham although the difference was found to be non-significant. The nitrate content of the muscle was the same in both type hams. Ether extract was not influenced by the processing treatment.

Bacon

The hot processed belly was heavier for the pre-chill method. This difference was attributed to the failure of the operator to cut at cor-

Table 1.—The Effect of Processing Method on the Properties of Ham

Ham	Unit	Mean		Std. error of mean
		Pre	Post[1]	
Unprocessed	Kg	7.73	7.48	.08
Boneless	Kg	4.37	4.42	.08
Lean Trim	Kg	0.48	0.53	.03
Fat Trim	Kg	2.40	2.19	.07
Bone Trim	Kg	0.84	0.78	.02
Fini-hed	Kg	3.57	3.58	.07
Loss	%	17.19	18.83	1.10
Shear value	Kg	3.09	3.28	0.16
Moisture	%	67.73	68.14	0.57

[1] Pre-chill or post-chill processing.

responding points in each carcass side. A difference in the length and width of the fresh belly and the subsequent cured and smoked bacon was readily evident. The freshly cut belly was always shorter and wider for the pre-chill method. Most of the difference was removed as the bellies cured, and smoked, Table 2. When the cured bacon was pressed and formed, the difference in length and width was further reduced. The post-chilled bellies when measured before processing were influenced by stretching as a result of chilling 24 hours in the carcass. Bellies from the pre-chill method contracted unless mechanical stretching force was applied during the heating and smoking period.

Since the ultimate measure of bacon yield depends upon the final pressed measurement, more knowledge can be obtained through a study of yield, Table 2. Post-chill bellies yielded smaller slices, but a few more slices than was true of the pre-chill bacon. The quantity of trim was no different for the two methods. A significant ($P<.05$) difference in the percent shrink was found between the pre- and post-chill processed bacons. The reason for this difference was in part due to the weight loss of the post-chill belly during the initial chill period. A slight day to day difference in the heating and smoking cycle may have caused a portion of the difference.

Several methods of measuring the influence of the pre- and post-chill processing method were used to account for the difference seen in the bacon slice. The bacon slice weight and a total weight of six slices from each slab indicated that the slices from the pre-chill method were heavier. This difference was also reflected by the greater slice depth, Table 3. Acetate tracings of six slices from each bacon were used to determine the total area and the area of fat and lean. The total slice area was significantly greater for bacon from the pre-chill method. Both the lean and fat areas were greater for the pre-chilled bacon. This difference was attributed to the fact that contraction occurred in the pre-chill belly. When the data were calculated on a percentage basis, the percent fat was greater while the percent lean was slightly less. Since the pre-chill bacon is both wider and deeper, one would expect the slice length and depth

Table 2.—The Effect of Processing Method on the Yield of Bacon.

Bacon	Unit	Mean		Std. error of mean
		Pre	Post[1]	
Unprocessed length	cm	51.95	60.11	0.67
Unprocessed width	cm	33.14	27.63	0.39
Smoked length	cm	52.68	54.99	1.63
Smoked width	cm	25.65	24.40	0.05
Pressed length	cm	52.30	53.44	0.75
Pressed width	cm	24.13	23.45	0.20
Slices	No.	173.97	177.45	4.04
Slice wt.	Kg.	4.27	4.13	0.08
Trim wt.	Kg.	0.48	0.48	0.05
Shrink	%	23.71	21.66	1.21

[1] Pre-chill or post-chill processing.

to agree, Table 3. When the weight of the bacon slice is used as a unit of measure, those from the pre-chill bacon were heavier, Table 4. This difference was reflected by a greater total amount of fat and lean. The percent lean in the slices from formed bacon slabs was essentially the same for bacon processed by both methods. The greater percentage of lean in the bacon slice was favored by the post-chill method. One would expect this to be the case since fat would contract along with the lean in the pre-chill belly.

Loin

The weight of the full loin, while non-significant was found to be slightly less for the pre-chill method. This same trend was reflected in the weight of the fat trimmed from the loins. Removal of excess fat from the pre-chill loin was found easier. In order to provide a smooth white surface to the fat, it was necessary to chill the loin in a special mold to produce a smooth fat surface.

Essentially no difference was found between the pre- and post-chill processed loins in the amount of total moisture remaining in the longissimus dorsi muscle after being cooked, Table 5. Warner-Bratzler shear value of the oven roasted loin muscle was not significantly different. Shrinkage as reflected by the thaw loss was larger for the pre-chill processed loins, but the difference was non-significant. Cooking loss was consistantly greater for the post-chill treatment, however, the difference was not significant.

Table 3.—The Effect of Processing Method on the Bacon Slice

Bacon	Unit	Mean		Std. error of mean
		Pre	Post[1]	
Slice area	sq. cm.	91.28	81.88	1.38
Lean area	sq. cm.	25.64	24.47	0.83
Fat area	sq. cm.	65.64	57.48	1.39
Lean	%	28.22	29.94	0.73
Fat	%	72.78	70.06	0.73
Slice length	cm.	24.70	23.22	0.30
Slice depth	cm.	4.00	3.83	0.06

[1] Pre-chill or post-chill processing.

Table 4.—The Effect of Processing on the Quantity of Lean and Fat in Bacon

Bacon	Unit	Mean		Std. error of mean
		Pre	Post[1]	
Slice weight	g	135.47	124.37	3.32
Lean	g	45.17	43.28	1.51
Fat	g	90.29	80.75	3.46
Lean	%	33.36	34.19	1.02
Fat	%	66.43	65.94	1.02

[1] Pre-chill or post-chill processing.

A detailed study of the muscle indicated a consistently larger fiber and one which possessed a greater degree of rigor as a result of the post-chill treatment, Table 5. The higher percentage of twisted fibers for the post-chill treatment would indicate that pork muscle had not undergone complete resolution of rigor during the 24 hour chill period.

Consumer eye appeal for cured meat makes brine diffusion through pork muscle and color fixation two factors of considerable importance in manufactured pork products. The quantity of nitroso-pigments extracted before and after exposure to light provided a measure of color fixation and stability. The data are presented graphically in figure 1. Prior to light exposure, there was no difference between treatments for the amount of cured ham nitroso-pigments. Significantly more pigment remained in the pre-chilled processed ham, exposed to 200 ft. C of light for 30 minutes, than in the post-chilled ham. Ham exposed to light for one through 24 hours showed that the pre-chill ham contained more nitroso-pigments although the difference was not significant. Pigment variation within treatment was greater for the pre-chill ham indicating the need for further work.

The zero time exposure was assumed to be 100 percent of the nitroso-pigments that could be extracted. This was then used to calculate the remaining amount of pigment at varied light exposure time. After 30 minutes exposure to light, the pre-chill processed ham contained 80.5 percent of the zero time pigment as compared to 65.9 percent for the post-chill samples. The greatest reduction in cured meat color would be expected during the first four of the exposure period. The difference in extractable pigments between one and six hours was significant. The pre-chill cured ham retained more nitroso-pigments than the post-chill processed ham. However, the color variation was greater. Commercially processed ham would be expected to have wide color variation due to the animal to animal and muscle to muscle variation.

Table 5.—The Effect of Processing Method on the Quality Attributes of Pork

Loin[1]	Unit	Mean Pre	Mean Post[2]	Std. error of mean	
Moisture	%	60.3	60.1	0.57	
Shear value	Kg	10.2	10.2	0.31	
Thaw loss	%	3.9	3.7	0.41	
Cooking loss	%	24.4	25.4	0.60	
		Longissimus dorsi Mean		Semimembranosus Mean	
		Pre	Post	Pre	Post
Fiber size	μ	76.8	79.5	70.1	74.2
Rigor fibers	%	58.0	59.0	29.5	30.0

[1] Longissimus dorsi muscle.
[2] Pre-chill or post-chill processing.

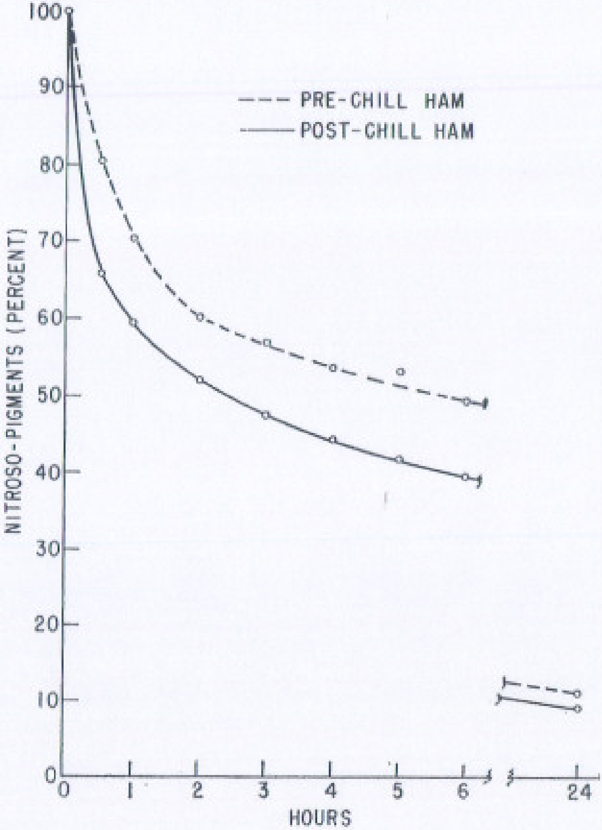

Figure 1. Relative nitroso-pigments remaining following exposure to light (200 ft.-C).

Bacterial numbers were based upon the quantitation of 19 pairs of ham. No pre-chill processed cured ham samples exceeded 109 bacteria per gram. Whereas, two cured post-chill hams yielded high count samples. Categorially, 68 percent of the cured pre-chill processed hams yielded samples from which no colonies could be plated or the count was less than 10 per gram. In the cured post-chill ham, only 53 percent of the samples had less than 10 colonies per gram when incubated at 37°C. Incubation of the tissues at the psychrophilic range (15°C) yielded low count samples. In most cases, the count was less than one psychrophile per gram. Explanation of the greater number of mesophilic to the psychrophilic count can be attributed to the method and manner of processing.

The reduction in total aerobic population due to the cured-cooked treatment effect is shown in Table 6. Ham injected with curing brine immediately after physical separation from the carcass had fewer bac-

Table 6.—Aerobic Bacterial Colonies in Pre- and Post Chill Processed Ham

	Treatment			
	Pre-chill		Post-chill	
	Uncured	Cured	Uncured	Cured
Colonies/gram[1] (N=19)	203.1	15.4	217.5	107.8
Std. dev.	502.0	27.4	337.0	303.5

[1] Plated on TGEA and incubated at 37°C.

teria per gram than ham chilled 24 hours before curing. The results of this work indicated no significant microbial problem in the concept of complete processing prior to chilling.

Summary

The cutting and fabrication of pork to a retail form prior to initial chilling provides products which have quality equal to the conventional processed products. The pork carcass may be cut immediately following the dressing operation and prior to chilling. Attractive conventional cuts can be made from the warm meat; however, the cuts must be formed during chilling. Excess fat removal is more easily accomplished prior to chilling. This is particularly true when it is necessary to remove intermuscular fat as in the ham. Yield of trimmed cuts were equal to those of the post-chill method. In some cases, more fat is removed from the pre-chill cuts, but more shrink loss is noted in the post-chill method. This loss has been attributed to moisture evaporation which occurs when the carcass is chilled.

The only difference in the size and shape of the wholesale cuts is that of the bacon. Pre-chill bacons were always shorter but wider than those from the post-chill method. The post-chill bacon slabs yielded smaller, but always a few more slices than was true of the pre-chill bacon. The post-chill method provided a greater percentage of lean in the bacon slice than did the pre-chill method. This would be expected since the fat must contract with the lean in the pre-chill method.

The weight of full loin was less for the pre-chill method. This was caused by the closer fat trim and ease of removing the belly at a point closer to the loin. Fat on the loin was smooth and white when chilled on a smooth surface.

Shear value for the longissimus dorsi and semimembranosus muscles indicated no significant difference in tenderness of pork when processed to a finished form prior to chilling. Water holding capacity of the fresh muscle was favored by the pre-chill method, as well as cure diffusion and color fixation. Muscle fiber size and degree of rigor were slightly greater in the post-chill pork.

The incidence of aerobic bacterial flora in the rapid processed ham is comparable to that of the post-chill processed ham. Greater reduction in total bacterial numbers were obtained with rapid processing. Knowledge obtained from the bacterial population studied revealed no significant bacteriological problems in the new concept of complete processing prior to chilling.

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Preliminary Performance of Ewes Involved in A Twice-Yearly Lambing Program

Fred A. Thrift, Mike B. Gould and Joe V. Whiteman

In any type of sheep enterprise where lambs are produced, the ewes need adequate and high quality feed during the last month of pregnancy for fetal development and also during the first two months after lambing for the production of milk. At other times of the year, the ewes are producing wool but otherwise are essentially being maintained, yet they still consume the equivalent of three pounds of air-dry feed daily. If these ewes could be made to lamb twice yearly or three times every two years, their efficiency would be greatly increased in terms of productivity per unit of feed consumed. Stockmen with a limited amount of feed could invest relatively more labor and management into such an enterprise and thus increase their productivity per acre and income per unit of capital investment.

Before such an enterprise can be properly evaluated, it is necessary to know what breeds or crosses would be most suitable for this type of program. Since twice-yearly lambing will involve at least one breeding season that is not normal for seasonal breeding ewes, those breeds and crosses that have been shown to exhibit the seasonal tendency least should be used in the initial studies. Ewes of Rambouillet and Dorset breeding are known to breed over a longer period of the year than other breeds. Previous information obtained from the Fort Reno Livestock Research Station indicates that Dorset x Rambouillet ewes conceive during May and June more readily than the Rambouillet ewes. Also, many observations suggest that many Dorset ewes will conceive during this period.

This is a preliminary report on a study being conducted at the Fort Reno Station to determine the genetic and environmental factors influencing twice-yearly parturition of Dorset, Rambouillet and Dorset x Rambouillet ewes.

Experimental Procedure

In the spring of 1964, a twice-yearly (fall and spring) lambing project was initiated at the Fort Reno Livestock Research Station in order to determine:

1. The performance of Dorset, Rambouillet and Dorset x Rambouillet crossbred ewes under twice a year lambing conditions when the breeding seasons center around May and November.
2. The average and variation in time from parturition to first estrus for the various breed groups and the two seasons involved.
3. The conception rates for the conditions listed under 2.

4. If the first year's performance will be maintained or improved during the second and third years of production as the ewes mature.

5. If breeding results are different when ewes are bred first for spring versus fall lambing.

Twenty 1963 spring-born, 1963 fall-born and 1964 spring-born ewes each of Dorset, Rambouillet and Dorset x Rambouillet (hereafter referred to as crossbred) breeding were obtained during 1963 and 1964. These ewes were obtained from flocks that customarily lamb their ewes both during the fall and late winter or early spring. All ewes were bred first when approximately one year of age, thus part of each breed group was bred first during the fall and the remainder during the spring. The following breeding, lambing and management procedures were and are practiced:

1. Fall breeding extends for 60 days beginning on October 20 and continues through December 19. Thus the spring lambing season begins about March 15 and extends until May 15.
2. Spring breeding also extends for 60 days beginning on April 20 and continues through June 19. This puts the fall lambing from about September 15 to November 15.
3. Ewes lambing more than 10 days before the next breeding season are exposed to a vasectomized teaser ram daily to detect estrus until the breeding season begins, after which they are exposed to a fertile ram. Later lambing ewes are exposed to a fertile ram approximately 10 days after lambing. Both marking harness and visual observation are employed to detect the ewes that are in heat.
4. All lambs are weaned at about 9-10 weeks of age in order that the ewes may recover sufficiently for their next parturition and lambing.
5. The ewes are weighed and scored for fat covering prior to each lambing season and at the end of each breeding season to aid in maintaining the ewes in a moderate condition relative to fatness.
6. The fall lambing ewes are supplemented with approximately one pound of grain per day plus alfalfa hay and are allowed to graze on wheat pasture together with their lambs.
7. The spring lambing ewes are also supplemented with about a pound of grain per day and permitted to graze on a bermudagrass-alfalfa pasture combination. The ewes are let out to pasture twice daily since their lambs are not permitted to leave the lambing barn area. This practice is followed in an effort to reduce internal parasite infestation as much as possible in the spring-born lambs.

8. The ewes are shorn approximately one week before the spring lambing begins. Also, they are tagged and crutched about one week before the fall lambing starts.

Results and Discussion

This is a preliminary report. All of the objectives of the study have not been attained at this time. However, certain trends are apparent and this discussion will be confined to a comparison of these breed groups and related observations when the ewes are given the opportunity to lamb twice-yearly under natural conditions.

The information presented in Table 1 summarizes the performance of the three breed groups for the two fall seasons (1964-65) and the two spring seasons (1965-66).

Fall Performance

The data presented (Table 1) indicates that a higher percentage of the crossbred ewes lamb in the fall than either the Dorset or Rambouillet ewes. On the average, these crossbred ewes lamb about the same time as do the Dorsets; whereas, the Rambouillets lamb about a week later than the other two breed groups. An examination of the percentage of ewes that lambed, rebred and conceived indicates a slight advantage for the Rambouillets compared to the other two breed groups. All ewes that lambed, rebred and conceived had an average conception date that was very similar. An interesting point to note is that the Rambouillet

Table 1.—Preliminary Performance of Dorset, Rambouillet and Dorset x Rambouillet Ewes Involved in a Twice-Yearly Lambing Program.

	Season					
	Fall (1964-65)			Spring (1965-66)		
Breed Group[1]	D	DxR	R	D	DxR	R
No. Ewe Seasons[2]	76	80	74	93	98	94
Av. Age of Ewes (mo.)	22	22	22	25	25	25
No. Ewes Lambing	33	45	32	72	81	84
% Ewes Lambing	43	56	43	77	83	89
Av. Lambing Date	Oct. 7	Oct. 9	Oct. 16	Apr. 4	Apr. 10	Apr. 6
No. Ewes Lamb., Rebred, Conc.	21	33	27	23	24	19
% Ewes Lamb., Rebred, Conc.	64	73	84	32	30	23
Av. Conc. Date[3]	Nov. 20	Nov. 23	Nov. 22	May 27	May 30	May 12
Av. Int. Lamb. to Conc.[3]	45	47	38	58	63	49
No. Lambs Born	42	58	37	108	128	107
Lambing Rate[4]	1.27	1.29	1.16	1.50	1.58	1.27
No. Lambs Reared	29	45	31	97	119	100
% Lambs Reared	69	78	84	90	93	93

[1] D = Dorset; DxR = Dorset x Rambouillet; R = Rambouillet.
[2] No. of records available for the fall and spring seasons.
[3] Based on the ewes that lambed, rebred and conceived.
[4] Lambs born per ewe lambing.

ewes had a shorter average interval (38 days) from lambing until the next conception occurred than either the Dorset (45 days) or the crossbred (47 days) ewes.

With regards to lamb production, the crossbred ewes were superior in number of lambs born as evidenced by their higher lambing rate. Further examination of the three breed groups reveals that the Rambouillet ewes reared a higher percentage (84 percent) of their lambs born followed by the crossbred (78 percent) and the Dorsets (69 percent). Even though the Rambouillets reared a higher percentage of their lambs, it is well to keep in mind that these ewes gave birth to fewer lambs than the other two breed groups.

Spring Performance

Table 1 indicates that approximately 12 percent more Rambouillet (89 percent) ewes lambed than did the Dorsets (77 percent); whereas, the crossbreds (83 percent) were intermediate between the two parental breeds. The average lambing date was similar for all breed groups. The percentage ewes that lambed, rebred and conceived was just the reverse of that indicated for the fall seasons. A higher percentage of the Dorsets (32 percent) lambed, rebred and conceived followed by the crossbred (30 percent) and Rambouillet (23 percent) ewes. It is worthy to mention that the figures are similar for all three breed groups, and based on these data should perhaps be interpreted as being quite similar. Of those ewes that lambed, rebred and conceived, the Rambouillet ewes had an average conception date 16 days earlier than the Dorsets or crossbreds. As was evident in the fall, the Rambouillet ewes had a shorter average interval (49 days) from lambing to conception followed by the Dorsets (58 days) and the crossbreds (63 days).

The crossbreds are superior, in the spring as they were in the fall, with respect to lamb production. The crossbred ewes that lambed produced about .16 of a lamb more per ewe than the Dorset or Rambouillet ewes. The percent lambs reared were similar for all breed groups, being slightly less for the Dorsets.

Discussion

Although certain trends are apparent with respect to the three breed groups, it is well to mention that none of the breed groups have performed very well under this type of management system. It was anticipated that the principal problem would be that of early resumption of estrual cycling and conception by the lactating ewes. All ewes must conceive 35 days post parturition if twice yearly lambing is to be accomplished and maintained without the lambing dates becoming later each season. It is evident from the information presented that the ewes have on the average not conceived with any degree of regularity 35 days after lambing.

Mortality for the three ewe breed groups has been slightly higher for the Dorsets. Seven Dorsets, four Rambouillet and two crossbred ewes have died during the period covered by this report. Four of the Dorset ewes have died from complications arising as a result of a prolasped uterus. Death losses among the crossbred and Rambouillet ewes can be attributed almost entirely to freak accidents (broken legs, etc.)

The information presented in Table 1 also indicates a difference in the survival rate of lambs born in the fall compared to those born in the spring. The combined performance of the three breed groups, within each season, indicates that the ewes reared approximately 77 percent of all lambs born in the fall and about 92 percent of the spring-born lambs. With these figures in mind, one might logically ask the question—why is there about a 15 percent advantage in survival rate for lambs born in the spring compared to those born in the fall?

Unfortunately, the answer to this question is not known but observations made on those lambs failing to survive during the fall suggests that low birth weights is associated with this high rate of mortality. During both fall lambing periods, several light weight lambs were born and the survival rate on these lambs has been rather low.

Figure 1 illustrates two types of lambs (with respect to birth weight) born during the fall. The small lamb is typical of the light weight lambs and the larger lamb is considered to be typical of those having a normal birth weight. The large lamb weighed 10.3 lb. at birth; whereas, the small lamb weighed 2.1 lb. In most all cases, these light weight fall-born lambs have been extremely small at birth but otherwise appear to be normally developed. Many of these small lambs are alive at birth but usually die within a few hours.

The light weight lambs are susceptible to the elements of nature and their chances for survival are greatly reduced. The larger more vigorous lambs at birth are those whose chances of survival are greatest and respond more favorably to an optimum environment throughout their growth period. These lambs are better able to utilize their dam's milk and make more rapid growth during the preweaning period.

A comparison of the birth weights of all lambs born in the fall (6.1 lbs.) with those born in the spring (9.2 lbs.) indicates about a 3 lb. advantage in birth weight for the spring-born lambs. Of the 343 spring-born lambs, 27 failed to survive. Those that did not survive had an average birth weight of 7.6 lbs. compared to 9.3 lbs. for the remaining lambs. A more extreme picture is evident after examining the birth weights of all fall-born lambs. The surviving lambs had an average birth weight of 6.8 lbs.; whereas, the 32 lambs failing to survive had an average birth weight of 3.7 lbs. A comparison of the average birth weights for fall-born lambs suggests that low birth weights very likely is a contributing factor to this high mortality observed.

No definite explanation can be given for these light weight fall-born lambs. However, some speculation into this matter appears to be in order. It is believed that high environmental temperature has some influence on the birth weight of these lambs, but just how this elevated

Figure 1. Comparative size at birth of two fall-born lambs. The large lamb weighed 10.3 lbs. at birth; whereas, the small lamb weighed 2.1 lbs. Most of these small, underdeveloped lambs are born during the first two weeks of the lambing season (last two weeks of September). Note the vigor of the large lamb.

temperature operates on an unborn fetus is not known. Where the ewes are maintained on pasture, as they are in this study, high environmental temperatures could perhaps bring about a reduced forage intake, which in turn may have an effect on the fetal growth. This condition should be repeatable by limited feeding if this explanation is correct. Such attempts have not given these results. Also the ewes should not be fat at lambing time. These ewes were fat.

As the environmental temperature increases, there may be an increased peripheral blood circulation as a means of eliminating the increased body heat. This in turn could create a nutritional deficiency to the fetus due to a reduced blood flow to the uterus. This explanation seems more plausable, but it may not be correct.

The ewes involved in this study are mated for fall lambing beginning on April 20 and continues through June 19. Consequently, the ewes that become pregnant are exposed to the hot months of July and August during much of their gestation period. This would be especially true for the ewes that conceive early in the breeding season. An interesting point to note is that of the fall-born lambs failing to survive, 56 percent were born during the first week and 62 percent during the first two weeks of the lambing season.

Summary

Twenty 1963 spring-born, 1963 fall-born and 1964 spring-born ewes each of Dorset, Rambouillet and Dorset x Rambouillet breeding were obtained during 1963 and 1964 to determine the performance of these three breed groups under twice a year lambing conditions when the breeding seasons center around May and November. All ewes were bred first when approximately one year of age, thus part of each breed group was bred first during the fall and the remainder during the spring.

Only preliminary conclusions can be drawn at the present time. In general the performance of the three breed groups had been superior in the spring to that in the fall. A higher percentage of all ewes lambed in the spring, gave birth to more lambs and reared a greater percent of the total lambs born. However, the percentage of ewes that lambed, rebred and conceived has been considerably lower in the spring than for the fall. This is to be expected since the normal breeding season occurs during the fall and consequently more of the ewes should lamb in the spring.

With respect to the individual breed groups, a higher percentage of the crossbred ewes have lambed in the fall; whereas, about an equal number of crossbred and Rambouillet ewes have lambed in the spring. The percent ewes that lambed, rebred and conceived has been in favor of the Rambouillets during the fall and similar for all breed groups in the spring. The Rambouillet ewes have consistently had a shorter average interval from lambing to conception followed by the Dorsets. The crossbred ewes require a longer interval from lambing until conception, but they have been superior to the Dorsets and Rambouillets in the number of lambs produced per ewe lambing. The Rambouillet ewes have produced less lambs per ewe lambing, both during the fall and spring seasons.

Neither of the three breed groups has performed in what might be considered as an optimum manner under this type of management system.

There appears to be about a 15 percent advantage in survival rate for the spring-born over the fall-born lambs. A comparison of the average birth weights of fall and spring-born lambs suggests that low birth weights is probably a contributing factor to this high mortality rate observed among fall-born lambs.

Studies will be continued with the original ewes until it is decided that a normal level of performance has been reached without any artificial treatments being imposed. Once this co-called normal performance is established and if this proves to be unsatisfactory, then it may be necessary to employ the use of certain hormones to induce estrus and ovulation in the lactating ewes.

Relationship Between Growth Rate, Probe Backfat Thickness, and Carcass Traits in Swine[1]

I. T. Omtvedt, D. F. Stephens, D. R. Rule and W. E. Sharp

Identification of superior breeding stock to serve as parents of the next generation is the foundation for all livestock breeding programs. This requires a thorough understanding of what each trait measures and how it is influenced by various other factors. It is also important that all potential breeding herd replacements be evaluated at the earliest possible age so that only individuals with the greatest genetic potential be permitted to reproduce and leave offspring in the herd.

This study was initiated to investigate the inter-relationships between growth rate, backfat thickness, carcass length, loin eye area, and lean cut yield for barrows and gilts. An additional analysis was also undertaken to determine the feasibility of evaluating potential breeding stock for growth rate and backfat thickness when they weighed 175 lbs. as compared to delaying selection until they reached 200 lbs. liveweight.

Materials and Methods

In the spring of 1966, 228 weaning pigs from 76 litters (23 OK14 Hampshire litters, 41 three-line cross litters, and 12 two-line backcross litters) were chosen for this study. Only litters containing at least two males and one female of approximately equal weaning weights and thriftiness were used. Within each litter, one male was randomly castrated in order to obtain boar-barrow-gilt littermate trios. All pigs were self-fed in confinement in groups of six pigs per pen from eight weeks of age to 200 lbs. liveweight.

Probe backfat measurements were taken on all pigs at 175 lbs. and again when they weighed 200 lbs., and age in days at each of these weights was calculated. Barrows and gilts were slaughtered at weekly intervals at Harris Packing Company, Oklahoma City, as they reached 200 lbs. and routine carcass measurements were taken 48 hours after slaughter.

The records were analyzed within line of breeding and sex. The within group correlation coefficients were transformed to z values and weighted by the reciprocal of their variance and corrected for bias. A Chi-square test of adjusted z values was used to determine the probability that the within line and sex correlations were from the same populations. Since the Chi-square values were not significant, the within line and sex z values were pooled to obtain the combined correlation coefficients reported.

[1] Research conducted in cooperation with Regional Swine Breeding Laboratory, AHRD, ARS, U.S.D.A. Special appreciation is expressed to Harris Packing Company, Oklahoma City for their cooperation in making it possible to obtain the carcass evaluation data at their plant.

Results and Discussion

Means and standard deviations for traits evaluated in this study are given in Table 1. The pooled correlation coefficients showing the inter-relationships between pre-slaughter and post-slaughter traits are summarized in Table 2, and the correlation coefficients for traits evaluated at 175 lbs. and at 200 lbs. for boars, barrows, and gilts are given in Table 3.

Growth Rate

In this study barrows reached 200 pounds live weight in an average of 147.5 days compared to 158.1 days for their littermate gilts. Pigs with slower growth rates tended to have less backfat and meatier carcasses than those that reached market weight at an earlier age (Table 2). Age at 200 pounds was closely correlated with yield of lean cuts on a live weight basis (r = 0.57) and on a carcass weight basis (r = 0.45), but was less closely correlated with carcass backfat thickness (r = —.19), carcass length (r = 0.16), and loin eye area (r = 0.16).

Backfat thickness

Backfat thickness was evaluated both on the live pig and on the carcass in this study. Carcass backfat measurements accounted for only about 35 percent of the variation in probe backfat thickness measurements (r = 0.59). Longer carcasses tended to have less backfat than shorter carcasses, but no significant relationship was obtained between loin eye area and backfat thickness. Both probe backfat and carcass backfat were negatively correlated with yield of lean cuts, but these relationships were higher when yield was expressed on a carcass weight basis than when expressed as a percentage of live weight (see Table 2). Probe backfat thickness was more closely correlated with lean cut yield than was carcass backfat thickness; therefore probe backfat measurements are a better indicator of muscling than carcass backfat measurements.

Table 1.—Means and Standard Deviations for Littermate Boars, Barrows and Gilts Evaluated in this Study.

Item	Boars		Barrows		Gilts	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Number of pigs	76		76		76	
Age at 175 lbs., days	135.8	10.0	131.8	9.1	139.3	9.9
175 lbs. probe, in.	1.06	0.09	1.17	0.38	1.11	0.12
Age at 200 lbs., days	150.0	11.6	147.5	11.2	158.1	12.9
200 lbs. probe, in.	1.19	0.11	1.36	0.12	1.26	0.15
Carcass backfat, in.			1.33	0.12	1.24	0.14
Carcass length, in.			29.8	0.26	30.3	0.29
Loin eye area, sq. in.			3.95	0.44	4.41	0.48
Lean yield of liveweight, %			37.6	1.69	39.5	1.66
Lean of carcass wt., %			54.2	2.03	56.3	1.70

Table 2.—Relationships Between Pre-Slaughter and Post-Slaughter Traits. Pooled Correlation Coefficients within Line of Breeding and Sex of Pig.

	Backfat probe	Carcass backfat	Carcass length	Loin eye area	Live wt. yield	Carcass wt. yield
Age at 200 lbs.	—.18*	—.19*	—0.16*	0.16*	0.57**	0.45**
Backfat probe		0.59**	— .42**	— .08	— .38**	— .49**
Carcass backfat			— .46**	0.11	— .26**	— .42**
Carcass length				— .29**	— .01	— .08
Loin eye area					0.53**	0.39**
Lean cuts of live wt.						0.83**

*significant at 5 percent level
**significant at 1 percent level

Carcass length

Gilt carcasses averaged 0.5 in. longer than the carcasses from their littermate barrows (30.3 in. vs. 29.8 in.). As shown in Table 2, longer carcasses tended to have less backfat ($r = -.46$) and smaller loin eye area ($r = -.29$) than shorter carcasses, but the correlations between length and lean yield were essentially zero.

Loin Eye Area

Gilt carcasses averaged 0.46 sq. in. more loin eye area than barrow carcasses in this study. Loin eye area at the 10th rib is often used as an indicator of carcass merit, but it accounted for only about 28 percent of the variation in percent lean cuts of liveweight ($r = 0.53$), and for only about 15 percent of the variation in percent lean of carcass weight ($r = 0.39$). Large loin area is a highly desired trait, but based on this data and other published results, it should not be over emphasized as a measure of overall muscle development in the carcass.

Yield of Lean Cuts

Gilt carcasses yielded approximately two percent more lean than barrow carcasses (Table 1). The correlation between lean cut yield on a live-weight basis and on a carcass-weight basis was 0.83. It is interesting to note that lean cut yield on a live-weight basis was more closely associated with age at 200 lbs. (0.57 vs. 0.45) and loin eye area (0.53 vs. 0.39) than was percentage lean of carcass-weight, but the relationship between backfat thickness and lean cut yield was higher on a carcass-weight basis than on a live-weight basis.

Evaluation at 175 lbs. Compared to Evaluation at 200 lbs.

In breeding programs designed to make genetic improvement, it is important to obtain accurate evaluation data on prospective breeding animals as early as possible to insure continued progress. When boars are selected on the basis of performance testing it is desirable to remove them from confinement as early as possible to give them an opportunity to "harden up" prior to breeding; also the test should be terminated before the boars start ranting and additional environmental variation is introduced that further confuses the expression of the trait being evaluated.

In this trial, the 76 littermate boar-barrow-gilt trios were evaluated for growth rate and backfat thickness at 175 lbs. and again at 200 lbs. at which time the barrows and gilts were slaughtered. The correlation coefficients between traits evaluated at these two weights are summarized for boars, barrows, and gilts in Table 3. Weaning weight accounted for approximately 32 percent of the variation in age at 175 lbs. and about 27 percent of the variation in age at 200 lbs. A slightly negative relationship existed between weaning weight and probe backfat, indicating that heavier pigs at weaning tended to have less backfat thickness when they approached 200 lbs., but magnitude of this correlation was quite low.

A close association existed between growth rate to 175 lbs. and growth rate to 200 lbs. The correlation was similar for boars and gilts but was slightly lower for barrows (0.92, 0.93 and 0.88, respectively). The correlation between age and probe was lower at 200 lbs. for boars and barrows than at 175 lbs., but the reverse was true for gilts (Table 3). The correlation between age at 200 lbs. and carcass backfat was also higher for gilts (r = —.31) than for barrows (r = —.08). No apparent explanation is available for this sex difference except more variation was observed in backfat thickness among gilts than among barrows.

The correlations between probe backfat measurements taken at 175 lbs. and those taken at 200 lbs. were 0.38 for boars, 0.53 for barrows,

Table 3.—Correlations Between Traits Evaluated at 175 Lbs. and at 200 Lbs. Liveweight for Boars, Barrows, and Gilts.

	Boars	Barrows	Gilts	Pooled
42-DAY WEANING WT. and:				
Age at 175 lbs.	— .54**	— .61**	— .56**	— .57**
Age at 200 lbs.	— .56**	— .47**	— .52**	— .52**
175 lb. probe	— .09	— .22*	— .16	— .15*
200 lb. probe	— .09	— .10	— .18	— .12
AGE AT 175 LBS. and:				
Age at 200 lbs.	0.92**	0.88**	0.93**	0.91**
175 lb. probe	— .06	— .25*	— .05	— .12
AGE AT 200 LBS. and:				
200 lb. probe	— .02	— .13	— .23*	— .13*
Carcass backfat		— .08	— .31**	— .19*
175 LB. PROBE and:				
200 lb. probe	0.38**	0.53**	0.66**	0.53**
Carcass backfat		0.57**	0.46**	0.52**
200 LB. PROBE and:				
Carcass backfat		0.60**	0.56**	0.58**

*significant at 5 percent level
**significant at 1 percent level

and 0.66 for gilts. This implies that selecting boars on the basis of backfat probe at 175 lbs. is not a good indicator of their backfat thickness at 200 lbs. while the ranking of gilts on the basis of backfat thickness at 175 lbs. is more nearly the same as their ranking at 200 lbs. The differences in backfat thickness for boars became more pronounced after they weighed 175 lbs.

Summary

Two hundred twenty-eight pigs representing 76 boar-barrow-gilt littermate trios were evaluated to investigate existing phenotypic correlations between growth rate, backfat thickness, and carcass traits, and to determine the relationship between traits evaluated at 175 lbs. and at 200 lbs. liveweight.

Growth rate, backfat thickness, and loin eye area were significantly correlated with yield of lean cuts for both barrows and gilts. Probe backfat thickness was more closely associated with lean yield than was carcass backfat thickness, but both backfat measurements were more closely correlated with lean cut yield on a carcass weight basis than on a liveweight basis. The correlation between loin eye area and percent lean of liveweight was 0.53 compared to a correlation of 0.39 between loin eye area and percent lean of carcass weight. Lean cut yield on a liveweight basis accounted for approximately 67 percent of the variation in lean yield of carcass weight in this study.

Pig weaning weight accounted for 32 percent of the variation in age at 175 lbs. and 27 percent of the variation in age at 200 lbs. The correlation between growth rate to 175 lbs. and growth rate to 200 lbs. was 0.93, 0.92, and 0.88 for gilts, boars, and barrows, respectively. The correlation between probe backfat measurements taken at 175 lbs. and at 200 lbs. was lower for boars than for either gilts or barrows, and the data revealed less individual variation in backfat thickness among boars at 175 lbs. than at 200 lbs. Based on these results it would be advisable to delay backfat thickness evaluation on boars until some point past 175 lbs. liveweight.

Differences in Growth Pattern and Carcass Development of Angus Bulls, Steers and Heifers*

James E. Tanner, Jack A. Richey, Richard L. Willham and Joe V. Whiteman

In recent years there has been an increased interest in comparisons of the growth and carcass development of young bulls, steers and heifers. It is generally known that steers gain more rapidly than heifers and previous research at this station and others has indicated bulls gain more rapidly than steers.

This study provides information from a relatively large number of cattle of similar genetic background and fed under similar conditions. The present study does not provide information relative to possible differences in consumer acceptability of meat produced from bulls, steers and heifers. However, reliable measures of growth and carcass development were obtained.

Materials and Methods

The data used in this study were obtained from 279 Angus calves raised in the Experiment Station herd at Lake Blackwell Range, Stillwater. The number involved in each sex and year were:

Year	1964	1965	Total
Bulls	35	50	85
Steers	30	47	77
Heifers	44	73	117

All calves were born during the spring and were not creep fed. One-half of the male calves from each sire were selected at random and castrated at an average age of 3 months. Calves were weaned at an average age of 205 days and shipped to the Fort Reno Station where they began a 168 day feeding period.

Weaning weights were adjusted to a 205 day basis as follows: Actual weaning weight minus birth weight divided by actual age in days times 205 plus birth weight. This weight was then adjusted for age of dam by multiplying by 1.15, 1.10, and 1.05 for calves from 2, 3, and 4 year old dams, respectively. No age of dam adjustments were made for calves from cows 5 years of age and older.

Bulls, steers and heifers were self-fed in separate groups, each receiving a similar 40 percent roughage ration each year. Average daily gain was calculated on a 154 day basis from weaning weight to final weight. Final weight being defined as the average of the 140, 154, and

*The assistance and cooperation of the beef division at Maurer-Neurer Packing Company, Arkansas City, Kansas is gratefully acknowledged.

168 day feedlot weights. Adjusted yearling weight is equal to the adjusted 205 day weaning weight plus 160 times average daily gain in the feedlot.

Upon completion of the feeding period, all animals were shipped to Arkansas City, Kansas, for slaughter. Average age at the time of slaughter was 12.3 months. Carcass conformation score, marbling score, carcass grade and estimated percentage kidney fat were provided by the same packing house personnel each year. Final carcass grades were in agreement with those of the USDA grader. Rib-eye area and fat thicknesses were measured from tracings made in the cooler after the carcasses were quartered in the normal manner between the 12th and 13th ribs.

Carcass cutability was calculated by the following equation developed and reported by Murphey *et al.* (1960).

$$\text{Cutability} = 52.56 - 4.95X_1 - 1.06X_2 + 0.682X_3 - 0.008X_4$$

where:

Cutability = percentage of carcass weight as boneless retail cuts from round, loin, rib and chuck
X_1 = single fat thickness over rib-eye, inches
X_2 = percentage kidney fat
X_3 = area of the rib-eye, square inches
X_4 = hot carcass weight, pounds

Results and Discussion

Growth

Average measures of growth and feedlot performance of bulls, steers and heifers are presented in Table 1.

Male calves were 4 pounds heavier than females at birth. Adjusted weaning weights were 464, 454 and 425 pounds for bulls, steers and heifers, respectively. Bulls and steers were considerably heavier than heifers at weaning, although the difference (10 pounds) between bulls and steers was somewhat less than is generally reported. It should be kept in mind that calves were castrated at an average age of 3 months and without any tendency to select the less desirable individuals for castration.

The data in Table 1 indicate that sex differences became more pronounced during the feedlot period. Bulls gained substantially faster in the feedlot than steers, and steers gained more rapidly than heifers. Average daily gains in the feedlot were 2.88, 2.46 and 1.99 pounds for bulls, steers and heifers, respectively, during the 168 day feeding period. It was interesting to notice that no serious behavioral problems were encountered in self-feeding groups of 35 and 50 bulls.

Table 1: Growth and Feedlot Measures of Bulls, Steers and Heifers

	Average			Standard Error[1]
	Bulls	Steers	Heifers	
Number	85	77	117	
Birth weight, lbs.	62.3[2]	----	58.2	.82
Weaning weight, lbs.[3]	464.0	454.0	425.0	5.25
Av. daily feedlot gain, lbs.[3]	2.88	2.46	1.99	.027
Feed/gain, lbs.	7.85	8.57	9.71	---
Yearling weight, lbs.[3]	925.0	848.0	743.0	7.39

[1] Standard errors based on steer values.
[2] Includes all males.
[3] See materials and methods section for calculation procedures.

All feeding was done on a group basis and therefore only group averages for feed efficiency were available. Pounds of feed per pound of gain were 7.85, 8.57 and 9.71 for bulls, steers and heifers, respectively. Feed efficiency results followed the pattern which would be expected since faster gaining animals generally require less feed per pound of gain. There appeared to be a definite advantage in feed efficiency for bulls over steers and for steers over heifers. Comparisons of feedlot daily gain and feed efficiency are depicted in Figure 1.

Adjusted yearling weights were 925, 848 and 743 pounds for bulls, steers and heifers, respectively. These weights reflect the differences in weaning weight and feedlot gain. Weaning, yearling and hot carcass weights of bulls, steers and heifers are shown in Figure 2. It is interesting to note that bulls were only 2.2 percent heavier than steers in adjusted weaning weight, but the difference had increased to 9.1 percent in adjusted yearling weight and 10.1 percent in carcass weight.

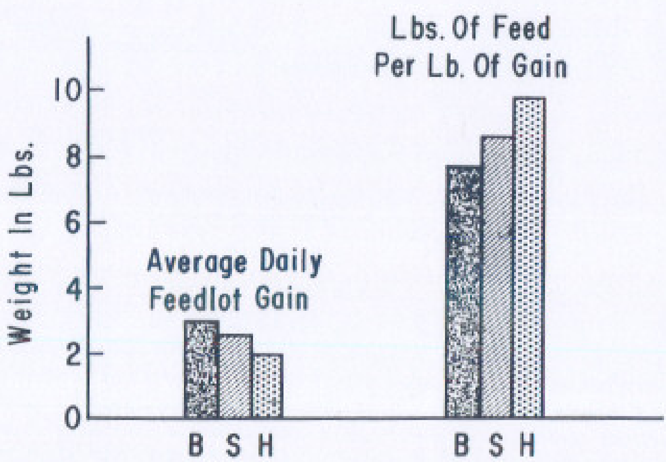

Figure 1. Average daily feedlot gain and feed efficiency for bulls, steers and heifers.

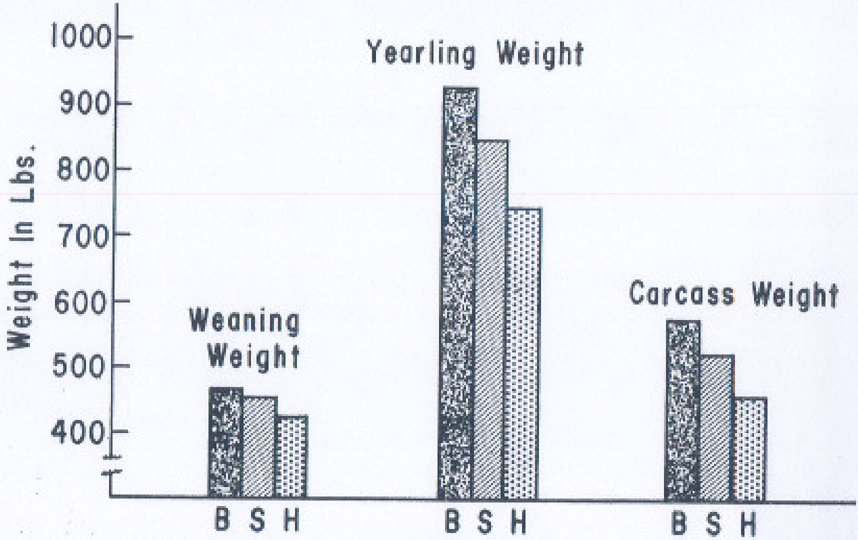

Figure 2. Comparisons of weaning, yearling and carcass weight of bulls, steers and heifers.

Carcass

It is important to keep in mind when reviewing the results from this study that all animals were fed for the same length of time. In some studies of this type cattle are slaughtered on a weight constant basis. Many of the carcass measurements might be different in the two cases because they are closely associated with carcass weight and dimensions.

Measures of carcass merit and development are summarized in Table 2. Large differences in carcass weight were found. The average carcass weights were 575, 522, and 457 pounds for bulls, steers and heifers, respectively. Although bull carcasses were heavier, they had less fat cover as measured by both average and single fat thickness between the 12th and 13th ribs. The average fat thickness was 0.54, 0.75 and 0.67 inches for bulls, steers and heifers, respectively. There was little difference between steers and heifers in fat thickness per hundred pounds of carcass weight. Estimated percentage kidney fat was considerably less for bulls (2.61 percent) than for steers (3.24 percent) or heifers (3.53 percent). When all of the measures of fatness are considered, we can conclude that bulls produced carcasses with substantially less fat while there was little difference in steers and heifers in this study. It must be remembered that different rations might have resulted in different gains and degrees of fatness and that the most desirable feeding regime may not be the same for the sexes.

Rib-eye area in square inches was significantly greater for bulls (12.16) than for steers (10.32) and heifers (9.88). However, there were only small differences in rib-eye area per hundred pounds of carcass

Table 2: Measures of Carcass Merit and Development of Bulls, Steers and Heifers

	Average			Standard Error[1]
	Bulls	Steers	Heifers	
Number	85	77	117	
Hot carcass weight, lbs.	575.0	522.0	457.0	5.95
Rib-eye area, sq. in.	12.16	10.32	9.88	.115
Rib-eye area/cwt. carcass	2.12	1.99	2.17	.021
Average fat thickness, in.	.54	.75	.67	.014
Single fat thickness, in.	.43	.61	.51	.014
Single fat thick./cwt. carcass	.074	.117	.113	.003
Kidney fat, percent	2.61	3.24	3.53	.087
Conformation score[2]	11.4	11.6	10.9	.15
Marbling score[3]	3.7	5.3	5.2	.08
Carcass grade[2]	8.8	10.9	10.4	.15
Dressing percentage[4]	61.9	62.7	61.3	----
Cutability, percent[5]	51.4	49.0	49.4	.140
Round yield, percent[6]	21.2	20.8	20.5	.109

[1] Standard errors based on steer values.
[2] Converted to the following numerical designations: low prime—13, high choice—12, average choice—11, low choice—10, high good—9, average good—8.
[3] Marbling score equivalents: moderate—1, modest—6, small—5, slight—4, traces—3.
[4] Calculated on basis of shrunk Ft. Reno live weight and hot carcass weight.
[5] Percent of carcass as boneless retail cuts from the round, loin, rib and chuck as described in materials and methods.
[6] Trimmed round expressed as a percent of hot carcass weight.

weight, with heifers actually having the largest ratio (Table 2). This would indicate the differences in rib-eye area were primarily due to differences in carcass weight.

Carcass conformation and marbling scores and final carcass grades are listed in Table 2. There was relatively little difference in carcass conformation scores of bulls (11.4) and steers (11.6) but both were higher than heifers (10.9). Bulls were significantly lower in marbling score, the averages being 3.7, 5.3 and 5.2 for bulls, steers and heifers, respectively (modest=6, small=5, slight=4, traces=3). The average final carcass grade for bulls was in the low end of high good, steers graded average choice and heifers low choice. The major reason for the lower carcass grade for bulls was probably their lack of marbling.

The percentage of carcass weight in trimmed round (round yield) is sometimes used as an indication of muscling in the carcass. Round yield percentages were 21.2, 20.8 and 20.5 for bulls, steers and heifers, respectively. Carcass cutability (percentage of carcass as boneless retail cuts from the round, loin, rib and chuck) values were 51.4, 49.0 and 49.4 for bulls, steers and heifers, respectively. If it can be assumed the cutability equation works equally well for different sexes, these results indicate bulls produced a greater percentage of lean meat in the carcass. Dressing percentages were 62.7 for steers, 61.9 for bulls and 61.3 for heifers.

Summary

Growth and carcass information from 85 bulls, 77 steers and 117 heifers were studied. All were Angus cattle raised and fed under similar conditions in each of the two years. One-half of the male calves from each sire were randomly selected for castration at an average age of 3 months. The cattle were self-fed for 168 days following weaning.

Male calves averaged 4 pounds heavier than females at birth. Heifers were substantially lighter than bulls and steers at weaning and bulls were only slightly heavier than steers.

Sex differences in growth became more pronounced during the feeding period. Average daily gain in the feedlot was 2.88 pounds for bulls, 2.46 pounds for steers and 1.99 pounds for heifers. Bulls were the most efficient in feed conversion requiring 7.85 pounds of feed per pound of gain as compared to 8.57 pounds for steers and 9.71 pounds for heifers. Differences in weaning weights and feedlot gains were reflected in yearling weights of 925, 848 and 743 pounds for bulls, steers and heifers, respectively.

Bulls produced significantly more lean meat with less fat than steers and heifers. There was little difference in carcass fatness of steers and heifers in this study. Bulls were higher in carcass cutability and yield of round. Steers were highest in dressing percentage with little difference between bulls and heifers.

Steers and heifers had a consistant advantage over bulls in carcass grade. Steers graded average choice, heifers low choice, and bulls in the low end of high good. The lower carcass grade for bulls was apparently a result of their deficiency in marbling.

The advantage of bulls in weight gain, feed efficiency and carcass cutability indicate the feeding of young bulls for slaughter may hold promise for increasing efficiency of production. Although, at the present time merchandising of bull meat may be a problem unless established marketing channels are available.

Literature Cited

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The Use of Oral Progestogens in Controlling the Estrous Cycle of Beef Cows and Heifers

E. J. Turman, J. E. Tilton, R. H. Edwards, T. D. Rich, R. L. Willham, Robert Renbarger and D. F. Stephens

Beef cattle producers must be constantly on the alert for any new technique that promises to increase the returns to a beef cow enterprise. The goal must be to have every cow in the herd producing at the maximum—in other words to start producing as early in life as possible, and thereafter be a regular producer of a heavy, high quality calf.

Artificial insemination is such a technique. It is widely used in dairy cattle herds, and probably has been the single, most important factor in dairy cattle improvement over the past 20 years. Although offering the same opportunity for the improvement of the beef herds, it has been used only on a very limited basis. Specific management problems that are peculiar to beef cattle herds have been the primary reasons why its use has been limited, particularly in commercial cow herds. Probably the most important of these problems is associated with the difficulties encountered in detecting heat in cows under range conditions. In most commercial herds the additional labor that would be required to do this over the entire breeding season greatly limits, and in many herds prohibits, the use of artificial insemination.

There is every reason to believe that artificial insemination would be much more widely used in beef herds if it was possible to reduce the difficulties presently associated with estrus detection. One of the most promising developments in this direction is estrus synchronization, which would result in all of the cows in a herd coming in heat within a few predictable days. Thus, the rancher could concentrate on heat detection and breeding only on these days and forget about it for the remainder of the days of that cycle.

Estrus synchronization was successfully accomplished on a research basis more than twenty years ago by means of injections of progesterone. However, among other shortcomings, this technique was not adaptable to practical management. The development, in recent years, of the oral progestogens—compounds with the same physiological activity as progesterone but effective when fed—has stimulated additional work in estrus synchronization. This work has progressed to the point where several pharmaceutical houses either now have, or soon will have, such compounds on the market.

Progesterone is an important hormone in the female reproductive cycle. There is, therefore, the possibility that the oral progestogens may have a number of other important applications in livestock production. One possibility that deserves study is that it may have an effect on the length of the post-partum interval from calving to first estrus. In most beef cows this period is some 60 days in length and is not a problem. However, in some cows, particularly young cows, this period may be unusually long and result in calving intervals considerably longer than

12 months. If these orally effective progesterone-like compounds can be used in cycling females to control the estrual cycle, there is the possibility that such compounds may be able to stimulate an earlier resumption of estrual activity in lactating cows.

This is a report of studies conducted over a three year period on the effect of an oral progestogen, 6-methyl-17 acetoxyprogesterone (MAP)[1] on: (1) The synchronization of estrus in cycling beef heifers and lactating 2- and 3-year old beef cows and the fertility at these synchronized estrus periods; and (2) Reducing the length of the post-partum interval from calving to first estrus and/or conception in 2- and 3-year old beef cows.

Materials and Methods

A total of five trials were conducted over a three year period at the Ft. Reno Research Station. Two trials (trials 1 and 2) were concerned with yearling heifers, and three trials (trials 3, 4 and 5) with lactating 2- or 3-year old cows which had calved in February and March. In all trials the oral progestogen used, 6-methyl-17 acetoxyprogesterone (MAP) was fed daily at a level of 180 mg./head/day for 18 days.

In most trials the cows and heifers were a part of other studies and, as a consequence, management practices differed somewhat between trials. However, within each trial the animals in the control and treated groups were managed as nearly alike as possible. Except in trial 2, the cattle were wintered on dry native grass pasture supplemented with 2 lb. cottonseed meal per day plus enough ground milo to maintain desired weight gains.

The breeding season was of approximately 3 months duration, with the time of starting varying somewhat but terminating in all trials on August 1. Breeding dates during the period of pasture mating were obtained by carefully checking the breeding pastures at least twice daily. The occurrence of estrus at times other than during the breeding season was determined by means of vasectomized teaser bulls running with the females. The cows and heifers were checked in October for pregnancy and an estimate made of the date of conception. In addition, in most trials, calving dates in the subsequent calving season were available to check these estimates of conception dates.

Summaries of the results of trials 1 and 2 are presented together in Tables 1 and 2 because they represent the response to be expected in cycling, non-lactating heifers. Likewise, the results of the trials with lactating 2- and 3-year old heifers (trials 3, 4 and 5) are presented together in Tables 3 and 4. However, because the trials were carried out under different conditions, the results of each trial must be considered separately and not compared directly to another trial. It is possible, however, to consider trends that emerge as trials of a similar nature are considered as a group.

[1] Repromix, The Upjohn Company, Kalamazoo, Michigan.

Results and Discussion

Trial 1. This trial was carried out in the Spring, 1964 to study the estrual response of cycling yearling heifers to MAP, and to compare the fertility to artificial insemination at the first and second post-treatment estrus. Sixty yearling Hereford heifers, 12 to 15 months of age and averaging 550 lbs. in weight, were divided into two groups of 30. Group 1 was scheduled to be inseminated at the second post-treatment estrus, and group 2 was scheduled to be inseminated at the first post-treatment estrus. To permit artificially inseminating all heifers during the same period, the time of starting MAP feeding was staggered. The heifers of group 1 were fed MAP for 18 days, March 25 to April 11. Following MAP they were checked for date of occurrence of first estrus but not bred. The heifers of group 2 were fed MAP for 18 days, April 15 tc May 2. Artificial insemination of both groups was begun May 1 and carried out for 6 days.

All artificial inseminations were made by an experienced inseminator from a commercial bull stud. The frozen semen that was used was prepared from a single ejaculate of a Red Angus bull with an excellent fertility record. Artificial insemination was practiced for only one service period. The heifers were then placed with Black Angus pickup bulls for which there was good progeny test evidence that they did not carry the recessive red gene. In this way the color of the crossbred calves would reveal, in borderline cases, whether the heifer had conceived to the artificial insemination or to natural service to the pickup bulls.

The data reported in Table 1 shows that good estrus synchronization was obtained when MAP was individually fed. Ninety percent of the 60 heifers were observed in estrus 1 to 6 days after the last feeding of MAP. The degree of synchronization is indicated by the fact that 76.7 percent were in heat by the end of day 3, with 55 percent in estrus on the second day.

Synchronization is also still apparent at the second estrus, since 95.3 percent of the 43 heifers observed for two heat periods were in estrus in a 9 day period from day 19 to day 27 after the last MAP feeding (Table 1). However, it should be noted that 88.5 percent were in estrus in a 6 day period, days 19 through 24. Thus, almost 90 percent of the heifers were observed in estrus within a 6 day period in both the first and second post-treatment estrus periods.

It is likely that these heifers were typical of the kind of heifers that would be expected to respond most favorably to the oral progestogens. All but 9 of the 60 heifers has been observed in first estrus, and it is likely that these nine would have attained puberty within the next few weeks. In addition they were a well bred, growthy group of heifers in excellent breeding condition.

Even with individual feeding, which should have insured that each heifer received her daily allotment of MAP, estrus was not completely suppressed during the MAP feeding period. There were 9 heifers (15 per-

Table 1. The occurrence of the first and second post treatment estrus in yearling heifers fed 180 mg. MAP/head/day for 18 days (Trials 1 and 2).

First Post-Treatment Estrus			Second Post-Treatment Estrus		
Days After Last MAP Feeding	Percent of Total Heifers on Experiment Observed in Estrus		Days After Last MAP Feeding	Percent of Total Heifers on Experiment Observed in Estrus	
	Trial I	Trial II		Trial I	Trial II
0	0	0	19	9.3	10.0
1	11.7	10.3	20	14.0	2.5
2	55.0	30.8	21	23.3	17.5
3	10.0	23.1	22	20.9	25.0
4	6.7	17.9	23	14.0	5.0
5	5.0	2.6	24	7.0	2.5
6	1.7	0	25	2.3	5.0
			26	2.3	7.5
			27	2.3	0
			28-32	0	12.5
No estrus Observed (%)	10.0	15.6		4.7	12.5
Number of Heifers Observed	60	39		43	40

cent) observed in estrus while on MAP treatment. However, estrus was synchronized in 6 of the 9 since they were also observed in estrus in the period 1-6 days after the last MAP feeding. This suggests that estrus while on treatment had little effect on subsequent synchronization after termination of feeding. The heifers were not palpated so it is not known whether they ovulated at this estrus while on treatment. Likewise, fertility at the post-treatment estrus of heifers that were in estrus while on treatment could not be checked. Only 1 of the 9 heifers showing estrus while on treatment was scheduled to be bred at the first post treatment estrus and she was one of the three heifers that did not return to estrus 1-6 days post-treatment.

The conception data is presented in Table 2. In this trial the conception to artificial insemination was low (33.3 percent), and was not affected by the post-treatment estrus at which it was carried out. The results reported by other researchers had indicated that this level of fertility might be expected at the first estrus, but fertility at the second estrus should be much better. It cannot be determined from the data available in this study whether the poor results obtained were the fault of the treatment, the semen or the inseminator. There is nothing to indicate, however, that the MAP treatment adversely affected conception rate during the entire breeding season. The overall conception rate of 93.9 percent is typical of what might be expected in a group of yearling heifers.

One observation that is not reported in the tables is worthy of mention. The heifers were bred artificially for 6 days, but calved to the artificial inseminations over a period of 19 days from January

Table 2. Conception data for yearling heifers following estrus synchronization by feeding 180 mg. MAP/head/day for 18 days (Trials 1 and 2).

	Trial 1 Bred A.I. on Post-treatment Estrus		Trial 2	
Item	First	Second	MAP Treated	Controls
Total heifers on treatment	30	30	41	42
Number bred	24	24	38	37
Number conceived first svc.	8	8	26	22
Percent conceived first svc. (%)	33.3	33.3	63.4	52.4
Total conception for breeding season (%)	90.0	96.7	90.2	85.7
Number of open heifers	3	1	4	6
Avg. calving date in next calving season	Feb. 27	Feb. 28	Feb. 21	Mar. 1

29 to February 17. Thus, it is apparent that precise control of calving date cannot be obtained by estrus synchronization through the feeding of oral progestogens.

Trial 2: This trial was carried out in the Spring, 1965 to study the estrual response of cycling yearling heifers group fed MAP, and the fertility to natural service at the second post-treatment estrus. This trial utilized 23 Hereford and 61 Angus yearling replacement heifers from the purebred herds of the beef breeding project at the Ft. Reno Research Station. The heifers ranged in age from 12 to 15 months and from 400 lb. to 650 lb. in weight. They had been wintered on wheat pasture until February 1, and then placed on native grass supplemented by alfalfa hay. Beginning March 15 they were group fed 1.5 lb. cottonseed meal and 3 lb. ground milo per head per day.

These heifers, as part of the cattle breeding project, had been previously allotted to 21 different breeding groups. It was necessary to take these breeding group allotments into account in further allotting the heifers by breeds to one of the two treatment groups. Group 1 served as untreated controls, while group 2 received 180 mg. MAP/head/day for 18 days beginning on March 26. The daily dose of hormone was mixed into the daily allottment of 1.5 lb. cottonseed meal. The heifers were group fed, however, ample trough space was provided so that all heifers of a group could eat at one time in an effort to insure that each heifer received her daily allotment of MAP. This time schedule of MAP administration was selected to permit breeding to start at the usual time of May 1, at which time most of the heifers should be coming back in estrus for the second time after the end of the MAP feeding period. The heifers were not bred at the first post-treatment estrus, but they were checked for the occurrence of this estrus by means of vasectomized bulls.

The heifers were placed in their previously assigned breeding groups on May 1 and ran with a fertile bull until August 1. Since some of the heifers were removed from the project before calving, the conception data presented in this report is based on observations of breeding dates as confirmed by rectal palpations.

Table 1 reveals that the estrual response following group feeding is comparable to that obtained following individual feeding. Estrus occurred in 84.4 percent of the heifers within 5 days after the last MAP feeding. As in trial 1 the largest percentage of heifers (30.8 percent) were observed in estrus on day 2. However, unlike trial 1, in which 86.6 percent of the heifers had been in heat by the end of day 3, 67.2 percent of the heifers in this trial were in heat in the same period.

A fair degree of synchronization was still evident in the second post-treatment estrus in which 75 percent of the heifers were observed in heat in the 9 days from day 19 to day 27. This compares to the 95.3 percent of the heifers in trial 1 observed in heat in the same period. In the 6 day period from day 19 to day 24 there were 62.5 percent of the heifers of trial 2 observed in heat, compared to 88.5 percent in trial 1.

Eleven (27 percent) of the heifers were observed in estrus while on treatment. However, 9 of the 11 (81.8 percent) were also observed in heat within 1-5 days after the end of MAP feeding, and 10 of the 11 mated in the first week of the breeding season with 6 conceiving. It is likely that this larger number of heifers in estrus while being group fed indicates all were not getting their full daily allotment of MAP. However, again, as in trial 1, estrus while on treatment does not appear to have had a marked effect on the response of the heifers to MAP.

Only 3 Hereford heifers (13.6 percent) and 37 Angus heifers (60.7 percent) had been observed in estrus prior to the start of MAP treatment. However, all of the heifers were apparently so near the point of attaining puberty that their response to MAP was typical of that observed in actively cycling heifers.

The conception data for trial 2 that is presented in Table 2 shows an advantage for MAP in every comparison, although the differences were not statistically significant. More MAP treated heifers conceived to first service (63.4 percent vs. 52.4 percent), more conceived during the entire breeding season (90.2 percent vs. 85.7 percent), and the MAP treated heifers conceived one week earlier on the average, as evidenced by the fact that they calved one week earlier in the subsequent calving season. This enhancement of reproductive performance at an estrus after the first post-MAP estrus has been reported by others.

All Trials With Cycling Yearling Heifers: In general the data obtained in these studies are typical of those reported by others. Treatment with MAP, and other oral progestogens, results in excellent synchronization of estrus in heifers at, or near, the age at which sexual maturity should occur. It is reasonable to expect to observe estrus in at least 90 percent of the heifers within 6 days in the first, and in 80 to 90 percent in a 6 day period the second post-treatment estrual period. The failure to observe this percentage of heifers in heat during this 6 day period of the second post-treatment estrus of trial 2 was likely largely due to the difficulty of accurately checking the heifers spread through 21 different pastures.

The way in which this degree of estrus synchronization would facilitate artificial insemination should be obvious. The labor involved in heat detection and insemination could be concentrated into two six day periods with the reasonable expectation that 80-90 percent of the heifers would be inseminated. Thus, 80 to 90 percent of the herd could be bred artificially through two heat periods with an outlay of 12 days of labor compared to the approximately 40 days that would be necessary without synchronization.

The numbers of heifers that would be in heat within a few days would rule out breeding by natural service as it is normally done. One way estrus synchronization could be combined with natural service would be if large numbers of bulls were available, as in trial 2. Another possibility would be to stagger the heifers as to time they were started on and taken off MAP feeding. Under present conditions it is difficult to find practical management value for either of these practices.

The data obtained in these studies do not permit reaching definite conclusions as to the effect of MAP on fertility. However, in general they support the reports from other research workers. Most of these other studies have shown that fertility at the first estrus after MAP is reduced somewhat. They have also shown that fertility at the second post-treatment estrus can be expected to be as good, and in many cases better, than that observed in the controls. There have been no reports to suggest that MAP, or any other commonly used oral progestogen, has any detrimental effect on the overall conception record of the breeding season.

Trial 3: This trial was conducted in the Spring, 1964 primarily to study the effectiveness of an oral progestogen, in this case MAP, in reducing the post-partum interval from calving to first estrus in two year old heifers. It was hypothesized that MAP might cause an earlier regression of the corpus luteum present during lactation. If the persistence of this corpus luteum is the reason for a prolonged post-partum intervals, and MAP caused it to regress, there is the chance that the cow would be stimulated to an earlier return to reproductive activity following calving.

Thirty eight 2-year-old lactating Hereford heifers were used in this trial. At the time of calving, in February and March, they were alternately assigned to either the treated or control groups. The heifers of the treated group were individually placed on treatment as they reached the 25th day after calving, and were fed, individually, 180 mg. MAP/head/day for 18 days. Fertile Hereford bulls ran with the heifers of both groups following calving and fertile matings were permitted at the first post-partum estrus regardless of the date of occurrence.

The estrus response of the 2-year old cows of trial 3 to 180 mg. MAP/day for 18 days is in sharp contrast to that reported in trials 1 and 2 for cycling heifers. The data reported in Table 3 shows that only 22 percent of the cows that received MAP starting on the 25th day after calving responded with estrus within 6 days after cessation of MAP feeding.

The conception data reported in Table 4, suggests that MAP in some way inhibited the occurrence of estrus and/or conception since the average date of conception of MAP treated cows was one week later than that of the controls. While the overall conception rate of the MAP treated cows is less than that of the controls, 94.4 percent as compared to 100.0 percent, it is acceptable, and there is no reason to believe that the MAP treatment had a detrimental effect on fertility.

It is evident that young lactating beef cows do not respond to MAP treatment started within a month after calving in the same way as do cycling heifers. It is also apparent that this MAP treatment sequence is not effective in reducing the post-partum interval. Apparently the heifer requires a set period of time to recover from the after effects of pregnancy and to rebuild the uterus before starting another gestation period.

Trial 4: This trial, carried out in the Spring, 1965, was a further

Table 3. The occurrence of estrus in lactating 2- and 3-year old Hereford cows fed 180 mg. MAP/head/day for 18 days (Trials 3, 4 and 5).

		Trial					
		3	4				5
			2-Year Olds		3-Year Olds		
Item		MAP	MAP	MAP + E	MAP	MAP + E	MAP
Total number of cows		18	10	10	7	6	22
Observed in estrus:							
Prior to start of MAP	—No.	0	2	2	4	4	10
	— %	0	20.0	20.0	57.1	66.7	45.4
1-6 days post-MAP	—No.	4	5	4	5	3	16
	— %	22.2	50.0	40.0	71.4	50.0	72.7
Cows in estrus prior to start of MAP feeding that were:							
In estrus 1-6 days post-MAP	—No.	-	1	1	2	3	8
	— %	-	50.0	50.0	50.0	75.0	80.0
Not in estrus 1-6 days post-MAP	—No.	-	1	1	2	1	2
	— %	-	50.0	50.0	50.0	25.0	20.0
Avg. interval from calving to start of MAP feeding of:							
all cows (days)		25	46	46	57	54	48
Cows in estrus 1-6 days post-MAP (days)		25	50	66	64	63	53
Cows not in estrus 1-6 days post-MAP (days)		25	39	60	46	45	40

Table 4. Conception data for 2- and 3-year old cows bred following feeding of 180 mg. MAP/head/day for 18 days (Trials 3, 4 and 5).

Item	Number of Cows	Conception Rate		Avg. Date of Conception
		No.	Percent	
Trial 3 (1964)				
Control	20	20	100.0	May 9
MAP	18	17	94.4	May 16
Trial 4 (1965)				
Control	11	7	63.6	May 15
MAP	10	10	100.0	June 3
MAP + ECP	10	7	70.0	June 10
Trial 5 (1966)				
Control	24	24	100.0	May 28
MAP	22	22	100.0	May 23

study of the effectiveness of MAP in young lactating beef cows, in this case both 2- and 3-year old cows. This study was not primarily an attempt to shorten the post-partum interval, but rather was designed to study the effect on estrual activity if MAP treatment was delayed so that the last feeding would come just prior to the start of breeding season on May 1. There have been some reports that estrogen injections would hasten the regression of the corpus luteum. If this is true, the combination of MAP plus a single injection of estrogen should result in better estrual response than does MAP alone.

A total of 90 Hereford cows, 34 three-year olds and 56 two-year olds, that had calved in February and March were used in this trial. The 2-year old cows had been used in trial 1, and the 3-year olds had been used in trial 3. The cows were divided within age groups into three treatment groups: group 1, untreated controls; group 2, individually fed 180 mg. MAP/head/day for 18 days, April 8 to April 25; and group 3, the same MAP treatment as group 2 plus a single intramuscular injection of 1 mg. estradiol 17B (ECP)[2] on the second day of the MAP feeding period.

The breeding season was begun on April 26 with hand mating to six fertile mature Hereford bulls carried out for 10 days. Beginning May 3 the cows were divided into 5 groups and pasture mated to one mature Angus and 4 yearling Hereford bulls until August 1. Each yearling bull was assigned to a breeding pasture as pickup bull for approximately 15 cows. All bulls had been semen tested and were believed to be fertile.

The estrual response of the cows of this trial are presented in Table 3. Only a few (20 percent) of the two year old cows had resumed

[2] ECP, The Upjohn Company, Kalamazoo, Michigan. An oil soluble 17(beta) cyclopentylpropionate ester of alpha estradiol.

estrual activity following calving, whereas, well over one-half of the three year old cows had been observed in estrus prior to the beginning of MAP treatments. A greater percentage of cows in both age groups responded with an induced estrus 1 to 6 days after last MAP feeding, when fed MAP alone rather than when fed in combination with ECP. As can be seen in table 3, 50 percent of the 2-year old cows receiving MAP alone compared to 40 percent receiving MAP + ECP were observed in estrus in the period 1-6 days post MAP. Comparable figures for the 3-year olds were 71.4 percent and 50.0 percent, respectively.

Probably the most important comparison revealed in Table 3 relates to the average interval from calving to start of MAP feeding for the cows that were in estrus 1 to 6 days post-MAP compared to those that were not. There is a definite tendency for cows that respond to MAP by an induced estrus to be those that have the longer post-partum intervals, and presumably are those ready, or nearly ready, to resume estrual cycling. These observations are supported by other studies that have shown that most beef cows require an interval of at least 60 days after calving to resume estrual activity. The results of this study would also tend to support the results obtained in trial 3, that MAP is ineffective in reducing the post-partum interval.

The conception data presented in Table 4 for trial 4 is data on the 2-year old cows only. Although the yearling bulls used had been semen tested and appeared to be fertile, one failed to settle the cows he ran with. Since he had been assigned to one of the two groups of 3-year old cows, it was decided to eliminate all conception data on 3-year olds.

Two things are apparent from the limited amount of conception data reported for trial 4. One is the controls had a very poor conception record, in fact the poorest of any group. However, the controls that settled did so some two weeks sooner than did the cows fed MAP alone. The group receiving the combination of MAP and ECP were delayed an additional week in conception, and had a much poorer conception rate than did those receiving MAP alone.

It is doubtful if any conclusion should be based on the conception data obtained in this trial, other than it does not appear that MAP had any deterimental effect on fertility. It does seem safe to conclude that the results of this trial do not suggest any reason for using a combination of MAP feeding and estrogen injection, but rather would indicate that such should not be used.

Trial 5: This trial, conducted during the Spring, 1966, was a further study of the effectiveness of MAP in 3-year old lactating heifers. These heifers had been used in trial 4 and many had bred late and, thus, had calved late. For this reason it was believed necessary to delay beginning of MAP treatment to have as many heifers as possible near a post-partum interval of 60 days. This was based on trial 4 where the results suggested that the length of the post-partum interval was the critical factor governing response of lactating heifers to MAP. It was further desired to start breeding no later than May 10, hence the dates picked for MAP administration.

A total of 46 Hereford cows used in trial 4 in 1965 calved early enough in 1966 to be used in this trial. They were divided as equally as possible on calving date into a MAP treated and untreated group. The MAP treated group was individually fed 180 mg. MAP/head/day for 18 days, April 21 to May 8. Hand mating to fertile Hereford bulls was carried out for 7 days following the last MAP feeding. The cows were then pasture mated until August 1. The conception data that is reported is based on breeding dates obtained by twice daily checking of the pastures as confirmed by rectal palpations carried out in October.

As can be seen from the estrual data in Table 3 and conception data in Table 4, there was a very acceptable response to MAP shown by the heifers in this trial. There was a good estrual response, 72.7 percent of the MAP-treated heifers in estrus 1-6 days post-MAP, and a perfect conception record in both the MAP-treated and control heifers. Again, as in trial 4, the heifers showing estrus immediately following MAP tended to be the heifers with the longest interval from calving to start of MAP. It was not essential that a cow be in estrus prior to the onset of MAP feeding to respond with an induced estrus, since only 8 of the 16 in a post-MAP estrus had been observed in estrus prior to MAP feeding. However, the data obtained in this trial suggests that if a cow was returned to estrus after calving there is a good chance she will respond to MAP by an induced estrus. In this trial 45.4 percent of the cows had resumed estrual activity after calving, and of this number 80 percent responded to MAP by coming into estrus 1-6 days post-MAP.

All Trials With Lactating Heifers: The results obtained in the three trials reported in this paper indicate that at least two factors detremine the effectiveness of MAP in synchronizing estrus in lactating heifers. One is the age of the heifers and the other is the length of the interval between calving and the start of MAP.

There appeared to be a tendency for 3-year old heifers to respond more readily to MAP than did 2-year old heifers. This might be expected since the reproductive performance of heifers at 2 years of age is usually well below what it will be at any other age. No data is available to indicate how much improvement, if any, in the response to MAP might be expected in mature cows over that observed in 3-year old heifers.

It would appear that if lactating cows are at, or very near, the post-partum interval at which they would normally resume estrual activity, they can be expected to show an estrual response to MAP similar to that observed in yearling heifers. It would appear, therefore, from the results of these trials that if a good response to MAP is desired, feeding should not start earlier than 50 to 60 days after calving. Only a limited number of cows that are treated shortly after calving can be expected to respond with an induced estrus. It also does not appear that MAP offers promise as a means of reducing the post-partum interval from calving to first estrus.

Animal Agriculture and Human Nutrition

Allen D. Tillman

Explosive increases in world population and mounting food deficits have created an urgent demand for more food. In fact, there appears to be need for a new source of food that can be brought into large scale production quickly enough to forestall the approaching famine and to buy time for medical and social scientists to bring the population under control. It is in this light that animal agriculture must be evaluated now and in the future. In this connection several points are pertinent as follows:

1. Animal protein is an excellent food and a generous supply improves human diets.
2. Much of the world is poorly supplied with animal products.
3. Animal protein will have to compete with other protein foods in the human diet.
4. Can animal agriculture survive?

1. Animal protein is an excellent food and a generous supply improves human diets.

Meat, milk, fish, eggs and game are liked by all people and these foods are of excellent quality. Per capita consumption of meat, eggs and dairy products in the United States are shown in Table 1. Not covered in this chart are the 4.5 kg. of fish and 1.1 kg. of game eaten by our people.

As protein is one of the most important nutrients supplied by animal products, it should be considered in more detail. When fish and game

Table 1. Per Capita Nutrient Consumption and Amounts Supplied by Meat, Eggs and Dairy Products in The United States (Byerly, 1966)

Nutrient	Consumed	Amount Supplied by Animal Products	Percent of Total
Energy, Kcal.	3150	1118	35.5
Protein, gm.	95	61.8	65.0
Fat, gm.	145	82.5	56.9
Carbohydrate, gm.	372	28.7	7.7
Calcium, gm.	0.96	0.74	81.9
Phosphorus, gm.	1.50	0.99	66.0
Iron, mg.	16.50	5.49	36.0
Vitamin A, I.U.	7800	3393	43.5
Thiamine, mg.	1.83	0.76	41.1
Riboflavin, mg.	2.26	1.63	72.3
Niacin, mg.	21.2	8.99	42.4

protein are added, present figures indicate that about 65 of the 95 gm. of protein consumed per day by Americans come from animal sources.

Byerly (1) has calculated the protein consumption by Americans from 1909 to 1963 and found that total consumption of protein has been relatively constant through the years, but that the consumption of animal protein has increased each year. It is of great interest to note that total protein intake has remained constant, even though the National Research Council (2) has shown that our total intake of protein can be reduced as the percentage of animal protein in the diet increases; animal proteins provide a better balance of amino acids than do the protein supplied by cereals.

"The FAO Committee (3) on protein requirements has estimated the minimal daily need for adults to be between 0.3 to 0.35 gm./kg. when the diet contains protein of maximal nutritive value." Proteins of animal origin are of maximal nutritive value and there is no doubt that high levels of animal protein in human diets are desirable.

2. Much of the world is poorly supplied with animal products.

Anderson (4) has published figures shown in Table 2, which indicate that not all of the world's people enjoy the level of animal protein in their diets as do those of us in the United States. He also projected these figures to 1970, in which he showed that population will increase from 3 billion to 3,613,000,000. Using a reference standard a per capita intake of 60 gm. protein intake per day, of which 10 gm. would come from animal protein, it appears that there was a deficiency of 8.7 million metric tons of non-fat dry milk, or its protein equivalent of other animal food products, in 1960 and that this will grow to 6.5 billion tons in 1970.

It appears that we were able to feed 3 billion people in 1960, although not very well for a large part of the world. Koonz (5) estimates that 500 million people are now underfed and that one-half of the world's

Table 2. Population and Animal Protein Consumption in 1960 (Anderson, 1964)

Area	People		Anmial Protein
	Millions	% of Total	Per capita per day, gm.
U.S.A.	180	6.0	64.0
Canada	18	0.6	64.0
Europe	425	14.2	40.0
U.S.S.R.	214	7.1	30.0
Latin America	209	7.0	23.0
Communist Asia	713	23.8	3.2
Other Asia	976	32.5	11.0
Africa	259	8.6	12.0
Oceania	13	0.4	69.0
Total	3,007		

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population or more suffer from varying degrees of malnutrition. It now appears that within the next 3 to 4 decades that we will have to provide food for an additional 3 billion people. In other words the world's population is now expanding at about 65 million per year (6).

To illustrate the point another way (6), if we were to assume that the per capita needs of protein is 23.7 kg., then we would have required 71.2 billion kg. of protein to feed 3 billion people. If population grows at 1.8% an additional 1.36 billion tons are required each year. After 10 years (7), 91 billion tons would be required and after 40 years, 142 billion kg. would be required annually (Table 3). A doubling of the present protein supply would not solve the problem since it is estimated that 62% of the world's population is underfed in protein. Also Horan (8) estimates that 50% or more of population of countries with average national diets are deficient in animal protein. The problem is probably more serious in affluent societies when nutrition habits of teenagers are considered.

It has been suggested by many workers that there is a direct correlation between the consumption of animal protein and per capita income. Income is only one factor affecting the consumption of animal protein. It requires land resources to produce animal protein and the United States has ample land resources for the production of animal proteins for the present and next generation. Most of the world is not so fortunate as citizens of the United States as is shown by the data of Table 4, which shows total land area, estimated area of arable land and of pasture, hectares of agricultural land per person and per animal unit in several geographical areas of the world (9). Animal units are arbitrarily assigned as follows: each cow, horse, camel, buffalo, mule, and ass has a value of one animal unit; each pig, sheep, or goat has value of 0.2 unit; and for each head of poultry, 0.02 unit. These figures, at best, are averages and there is doubt regarding the estimation of grazzing land available. For example, several authorities in the United States believe that the United States has more land which could be used for grazing purposes.

The world had one person for each 1.3 hectares and one animal unit for each 2.5 hectares in 1960. Communist Asia, China, has only 0.4 hectare per person but has an animal unit per 1.9 hectares. Even though population pressure has made these people utilize many plant products as human food rather than to feed these to animals, China

Table 3. Future Protein Needs (Gray, 1964)

Population	Protein needs[1] billion (kg)
Three billion	71.20
Increase 1.8% per year	1.36
After 10 years	91.00
After 40 years	142.00

[1] Annual per capita need, 23.7 kg.

Table 4. Total and Agricultural Land in The Various Areas of The World, and Agricultural Land Per Person and Per Animal Unit in These Areas (FAO, 9)

	Land				Agricultural land (1960)	
Area	Total	Arable	Grazing	Total agri-cultural	Per person	Per animal unit
	----	Millions of hectares[1]		----	Hectares	Hectares
U.S.A.	936	185	257	442	2.4	3.4
Canada	998	42	21	63	3.5	3.9
Europe	493	153	90	243	0.6	1.2
USSR	2240	230	370	600	2.8	4.4
Latin Am.	2272	102	386	488	2.3	1.7
China	976	109	178	287	0.4	1.9
Other Asia	1740	341	246	587	0.6	1.4
Africa	3020	253	591	844	3.3	4.4
Oceania	854	34	458	492	37.8	7.0

[1] One hectare is equal to 2.47 acres.

still has more animal units than the United States (147 vs. 128 million units). Thus Byerly emphasized"—population pressure is not likely to eliminate livestock as producers of animal food. Their scavenger role is an important one."

3. **Animals will have to compete with other protein foods in the human diet.**

Animal protein will have to compete with other sources of food protein. Also it is known that some livestock compete with man for food. For example, swine and poultry consume feed grains which humans can consume directly. It is generally known that humans obtain more edible protein per unit of crop when the plant food is consumed directly rather than when the crop is fed to livestock, which are later eaten.

Table 5 shows the amount of edible protein, which it is estimated could be supplied from good land when the products are fed to beef cattle, dairy cattle, or when planted to soybean or alfalfa, with the protein contained therein being processed for human consumption.

Byerly (1) has put the figures in a more realistic form. His figures indicate that milk cows, as presently managed in the United States, convert feed protein with an efficiency of about 30 percent; laying flocks being 20 percent; and broilers being 25 percent. It is estimated that the cattle industry, in general, provides food protein with an efficiency of about 10 units of feed protein for 1 unit of food protein. Swine appear to be somewhere between beef cattle and laying hens. These figures make it obvious that animal products cannot compete with those of plant origin or, perhaps, synthetics if efficiency is the sole criteria.

Agricultural Economists and others have compiled figures which indicate that during the last 25 years we have made tremendous improvement in feed efficiencies in poultry but that such improvements in

Table 5. Estimated Edible Protein Production Per Hectare of Good Land

Commodity	Per Year (kg)
Beef	50
Milk	86
Soybean	504
Alfalfa	675

other animals have not been so dramatic. The major improvements in dairy, and beef, production have come about because of decreased mortality and increased grain feeding. Many people ask how long can we afford the extensive grain feeding now used in both industries. It is true, however, that grain feeding has allowed extensive use of urea as a protein substitute. For example, it is estimated that we will be utilizing 200,000 tons of feed-grade urea by 1970 in feeding our beef and dairy cattle, sheep, and goats. This will represent the replacement of 667,000 tons of soybean or cottonseed meal.

Most world authorities agree that we cannot expand animal production at a rate to provide all people with an adequate diet. For this reason much atention is being given to developing other protein sources without necessarily de-emphasizing animal production. A partial list of non-animal protein sources follows:

Algae. The common algae which grows on farm ponds has simple nutrient requirements and can convert non-protein nitrogen to protein at a fast rate. The quality of the protein appears to be good and easily produced.

Microorganisms. The culture of microorganisms, which have high protein content, appears to have been initiated by Champagnat *et al.* (11) in 1963. This report stimulated many major oil companies to initiate feasibility studies on fermentation processes based upon crude petroleum products. It appears possible to treat 500 tons of gas oil per day in a continuous fermentation unit and recover 50 tons of dried microorganism and 450 tons of improved oil; the oil being improved because the microorganisms used the waxes as an energy source. Their only other dietary needs are sources of simple nitrogenous compounds and minerals. Tables 6 and 7 show the composition of the protein-vitamin concentrate.

Champagnat *et al.* (1963) compared the rate of production of protein using microorganisms with that in a bovine: "One 500 kg. cow suitably fed by grazing synthesized 0.5 kg. protein per 24 hours. Five hundred kg. of living microorganisms in a continuous fermentation unit, suitably fed with petroleum hydrocarbons, nitrogen, minerals, and air should produce, according to our experience, 2500 kg. microorganisms in 24 hours in which there are 1250 kg. of protein, thus industrial production may be 2500 times as fast as the natural method." Research on petro-protein production appears to be under the sponsorship of several major oil companies and techniques remain as secrets of these companies.

Table 6. Composition of Protein-Vitamin Concentrate Produced From Microorganism Fed Petroleum Waxes (11)

Ingredient	%
Dry matter	93.00
Total Nitrogen	6.90
Protein	43.60
Fat	18.50
Carbohydrate	21.90
Minerals	4.40
Calcium	0.21
Pho'phorus	1.25
Potassium	0.50
Sodium	0.06

Table 7. Percentage Amino Acid Composition of Microorganism Protein Obtained From Microorganism Grown On Petroleum Waxes (11)

Amino acid	Wheat Flour	Beef	Milk	Petroleum Produced Protein
Leucine	7.0	8.0	11.0	7.0
Isoleucine	4.2	6.0	7.8	3.1
Valine	4.1	5.5	3.1	8.4
Threonine	2.7	5.0	4.7	9.1
Methionine	1.5	3.2	3.2	1.2
Cystine	1.9	1.2	1.0	0.1
Lysine	1.9	10.0	8.7	11.6
Arginine	4.2	7.7	4.2	8.0
Histidine	2.2	3.3	2.6	8.1
Phenylalanine	5.5	5.0	5.5	7.9
Tryptophan	0.8	1.4	1.5	1.2
Percent Protein	13.2	59.4	33.1	43.6

The production of protein from petroleum waxes outlook is thought to be bright by many authorities. There appears to be an unlimited supply of crude petroleum waxes, which is the energy source and the process could be of mutual benefit to the petroleum industry. Using the figures, which are available, it would appear that one ton of microorganism protein could be produced for each 50 tons of crude petroleum processed. If this were extended, it would appear that only 150 million tons of petroleum would have to be processed to produce enough protein to meet the need of the world's population of human beings. As this would represent less than one-sixth of the 1500 million tons of paraffinic petroleum refined last year, it does appear possible to produce 10 times as much protein as we need in human nutrition. There remain many production problems before this can be applied.

Strong efforts are being made to include soybean, cottonseed, peanuts and sesame meal in the diets of people in protein-deficient areas. Likewise, there is much effort devoted toward the use of soybean protein in our own affluent society. Food processors have used for many years soy flour as a binder and extender in meat loaf, sausage, and bakery products. Edible grade soy protein is a more recent manufacturing venture. The products are prepared from high quality, dehulled soybean from which the oil and soluble constituents are extracted leaving a product containing 70 percent protein. Further extraction produces an isolated soy protein, which contains 90 percent protein. Both products are widely used in cereal products, bread, meat products, baby food and candies. Spun soybean fibers are now being used as meat in hot dogs, beef, chicken, turkey, and other meat dishes.

There is much effort now being placed upon the utilization of cottonseed protein by the human population of Latin America. Altschul (12) reported that over 5 million tons of this product were used for this purpose in 1965. Research on this product is quite active, especially since cottonseed meal contains a toxic product, gossypol. Amino acid supplementation of diets containing the oil meals plus the cereals made the combination equal in quality to milk or meat protein (13); the amino acids were methionine, lysine and threonine. All of these amino acids can be made synthetically. In fact, lysine, methionine and methionine hydroxyanalogue are manufactured commercially.

The most limiting amino acid of wheat is lysine. Many people have proposed that the bakeries in the United States enrich the bread from wheat with lysine, but our authorities doubt this necessity because of our consumption of milk and meat products, which contain high levels of lysine. Perhaps consideration should be given to the enrichment of the wheat now sent to India. For example, if to the 15 million tons of wheat sent to India in 1964 we had added 0.26 percent lysine it would have made it a better source of protein. Such supplementation would have required 38,300 metric tons of lysine, more than the world supply. The price of lysine is $8.60 per kg.; however, if the demand were increased to 30 to 50,000 tons per year, the price would drop to $2.00 per kg. (10).

Some authorities believe the ultimate in protein nutrition will have been reached when we can synthesize all of the amino acids in amounts and at a price, which would allow us to feed our entire population from this source.

England is supporting research designed to extract protein from green plants. Pirie (14) recently reviewed their progress and I quote from his review,"—machinery was perfected for the processing of fresh leaves, both at the 1-ton-per-hour rate and in 100- to 200 kilogram batches, and extracting one-half to three-fourths of the protein. The protein is better nutritionally than most seed protein and can be presented on the table in palatable forms. Leaf protein is probably one of the foodstuffs that will be used, especially in the wet tropics, in ameliorating the protein shortage that now exists."

Corn. Currently there is much interest in the mutant strain of corn developed by the Purdue workers. Rats fed Opaque 2 corn gained three times as fast as those fed the best Indiana hybrids (15). Preliminary tests with chicks, swine and humans indicate that the product is superior when fed to these species. Because this drastic change in nutritional value is the result of a single mutant gene, work is underway with the objective of uncovering such mutants in milo, wheat, rice, barley and other grains. If the other cereals can also be improved by the introduction of a single mutant gene, we should make further progress toward meeting the protein needs of our expanding population.

4. Can animal agriculture survive?

Historically livestock have been scavengers from man's food supply. Ducks, chickens, geese and pigs have been used in much of the western world. Goats have had the same function in much of the Middle East. We must turn our attention to finding better ways of using these animals for this purpose. New Jersey workers have recently re-evaluated the use of garbage in swine feeding (16). Several research stations have reported that chicken litter can serve as a protein source for fattening cattle.

There are 500 million tons (fresh weight) of manure produced by livestock in this country alone. Are we in America making efficient use of this product? The answer is, of course, no. In fact, manure disposal appears to be a major problem of the present cattle feedlots. It is interesting to contrast this with Wetsern Europe, where animal manure is a valuable commodity.

More coarse roughage such as straw, corn cobs etc. can be used as feeds for our cattle and sheep fed maintenance rations. Animals can be used to utilize offal found in any quantity anywhere. For example, there is much blackstrap or cane molasses available in quantity in many parts of the world at an economical price. In some countries it is used to spread on dirt roads to keep down dust. This product is a valuable livestock feed. In a recent experiment, the author fed growing sheep a ration composed of one lb. of cottonseed hulls and allowed the sheep free access to a liquid mixture composed, in percent, of: cane molasses, 94.0; urea, 4.0; minerals, 2.0; and vitamins A and D. These animals gained 0.11 lb. per day and produced excellent carcasses. Such gains are poor by production standards in the United States but are remarkable when it is considered that 90 percent of the protein was supplied by urea and that only synthetic or waste products were fed.

Wood manufacturers have found that the processing of wood to make pressboard and other pressed wood products require much steam pressure and high temperature. In such treatment, about 10 percent of the hemicellulose is extracted. Feeding results with cattle and sheep indicate that this product is a good source of carbohydrate. What about a diet composed of wood molasses, urea and low quality roughage for ruminants? Experimentation in such areas must be increased for there are literally millions of tons of wood fibers burned yearly because of disposal problems. Such practices increase air pollution problems in America.

The world has millions of hectares of land, which will produce nothing but forage. This forage must be used for the production of animal products for human consumption. This involves public lands in the United States and elsewhere. Such land must be fertilized, grazed properly, and properly supplemented with all elements needed for optimum animal growth.

Man must obtain better utilization of the forages available now. Figure 1 (Lewis, 17) shows how one could increase protein production by grain supplementation when the nitrogen level of forage is too high. Farmers, by adding grain in the proper amount and proper time to cattle or sheep grazing forages having excess protein, could possibly produce more human food in milk or flesh than could be obtained if the grain were eaten directly.

Mineral imbalances are important factors when the stress of high production is placed on livestock. Figure 2 shows some interrelationships of minerals. We much seek these out and correct the imbalances by feeding supplemental minerals or by making major changes in soil fertilizers.

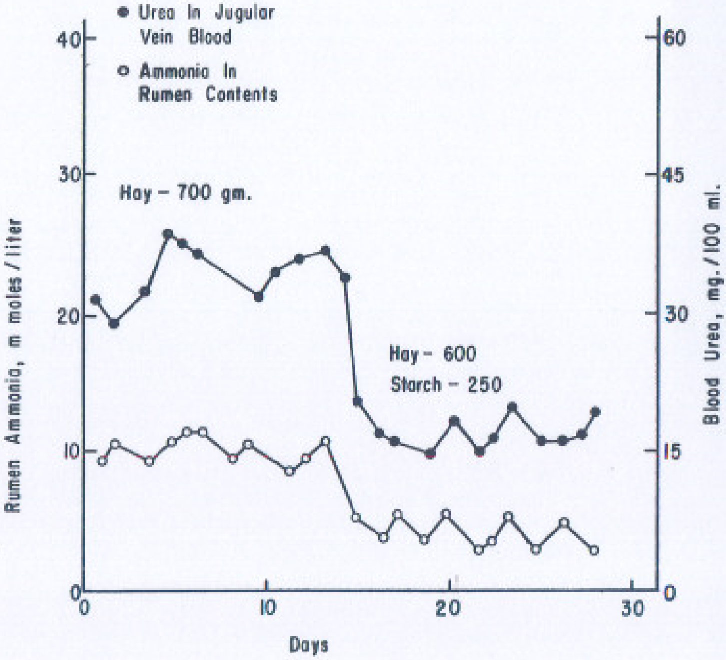

Figure 1. Blood urea and rumen ammonia concentration of changing the diet of sheep. (Lewis, 1957)

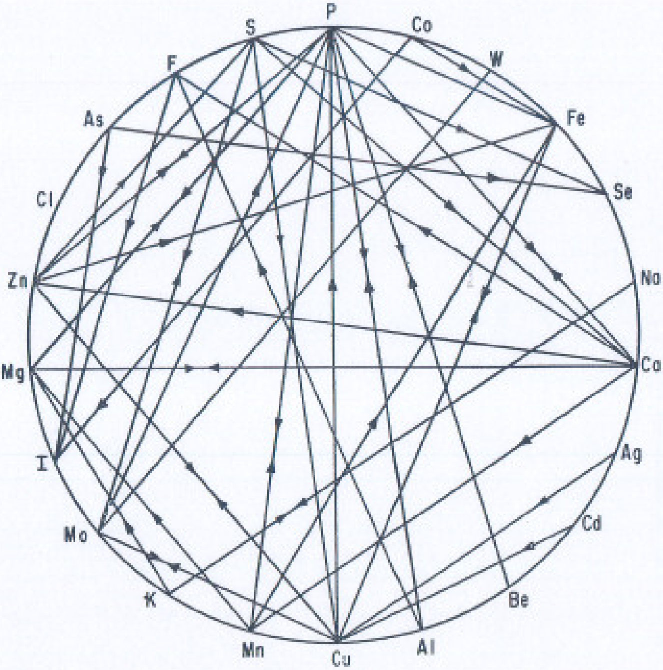

Figure 2. Mineral interrelationships in animals.

Animal products are nutritious and we like them in our diet. The production of these products is expensive in terms of conversion of feed protein to food protein; however, animals can be used as scavengers of human food supply. Man must investigate ways of utilizing our animals better for this purpose. Man must also obtain more animal products from the lands, which can not be used to grow crops other than forages. Proper supplementation of forages as regards minerals, protein and energy are prime considerations.

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The Cumulative Influence of Level of Wintering on the Lifetime Performance of Beef Females Through Seven Calf Crops

Craig Ludwig, S. A. Ewing, L. S. Pope and D. F. Stephens

The type of forage available to range beef cows during the winter months dictates in many cases that supplemental protein and often supplemental energy be provided to insure acceptable cow performance.

The amount of supplemental feed required is of economic importance in terms of feed cost as well as the ultimate influence on reproductive performance and milk production of the dam.

Several experiments have been conducted at this station which relate to this subject, and progress reports have been made periodically. This report summarizes performance of spring-calving cows wintered at different levels from weaning through seven calf crops.

Experimental Procedure

One hundred twenty weaner heifer calves were selected from the Ft. Reno herd as experimental animals and started on tests at an average age of approximately 8 months at weights of near 475 lbs. One-half of the above number was started as weaner calves in the fall of 1957 and the balance started as weaner calves in the fall of 1958. The heifers were allotted to four groups of 30 each on the basis of sire, dam's productivity, age, grade and weight. The winter feeding program was started each year in early November and was terminated when green grass was ample in the spring around April 15.

The experimental treatments employed were designed to result in selected winter weight change paterns as follows:

Lot 1 (Low). No gain the first winter as calves, with a loss of approximately 20 percent of fall weight during subsequent winters as bred females.

Lot 2 (Moderate). Gain of 0.5 lbs. per head daily the first winter as calves, with a loss of 10 percent of fall weight during subsequent winters as bred females.

Lot 3 (High). Gain 1.0 lbs. per head daily during the first winter as calves, then less than 10 percent loss of fall weight during the subsequent winters as bred females.

Lot 4 (Very High). Self-fed a 50 percent concentrate mixture during the first winter as calves and during subsequent winters as bred females.

It should be noted that the above weight change patterns are changes from November to mid-April and include weight loss at calving and post calving loss until green grass is ample in the spring.

One-half of the females in Lot 4 were reverted to the moderate level the fourth winter to study the effects of a very high level the first three winters followed by the moderate level during subsequent winters. This group from Lot 4 was designated as Lot 5 and will be referred to as such in this report.

The daily level of winter supplemental feed consisting of cottonseed cake or cottonseed cake and ground milo was adjusted periodically to produce, as nearly as possible, the weight change patterns outlined above. The low level females were confined to dry lot during the early part of each winter and fed wheat straw to initiate the desired weight loss. After this initial period they were maintained on native tall grass pasture during the winter with supplemental feeds as necessary to produce the desired weight change.

The females in all other treatments were maintained on native tall grass pastures during the entire winter and fed the appropriate levels of supplemental feeds. All animals had free-choice access to a mineral mixture consisting of two parts salt and one part steamed bone meal throughout the year. All groups were grazed on native pasture during the summer months.

The heifers were exposed to bulls as yearlings and calved first as 2 year olds. Detailed records have been collected on weight change patterns, skeletal development, reproductive performance, birth and weaning weights of calves and milk porduction which was estimated periodically during the lactation period by a standard procedure which involves weighing the calf before and after nursing.

Results

The results will be presented and discussed under separate headings designated by the general types of observations involved.

Weight Change Patterns

The periodic weights observed during the study to date are shown in Table 1 and designated as fall and spring weights. The spring weights in each instance were taken in early April, therefore, these weights after the heifers were two years of age reflected weight changes from fall to spring and include weight losses incident to calving and early lactation. The rate of development of the heifers can be followed for each treatment by observing the progressive weights for a given time each year.

Table 1. Weight change patterns of beef females wintered at different levels.

Lot No.		1	2	3	4	5
Wintering Level		Low	Moderate	High	Very High	Very High to Fourth Winter then Moderate
Calf Crop Number	Age in Months					
	7 Fall	473	472	475	488	457
	12 Spring	462	569	620	768	725
	18 Fall	738	829	859	892	892
1	24 Spring	571	679	789	1048	1095
	30 Fall	848	880	959	1084	1050
2	36 Spring	667	829	889	1182	1182
	42 Fall	968	1037	1066	1197	1171
3	48 Spring	807	934	991	1438	925
	54 Fall	1103	1137	1155	1328	1079
4	60 Spring	850	943	1025	1566	915
	66 Fall	1142	1186	1212	1430	1133
5	72 Spring	857	930	1043	1627	928
	78 Fall	1191	1240	1289	1480	1280
6	84 Spring	874	981	1132	1374	976
	90 Fall	1146	1182	1262	1372	1172
7	96 Spring	926	1011	1139	1248	971
	102 Fall	1215	1238	1294	1322	1198

Using the successive spring weights taken at the beginning of the grazing season to reflect the development patterns, these spring weight changes can be seen in Figure 1. It can be seen in Figure 1, that the average spring weight of one-half of the females in very high level the first three winters and then switched to the moderate level during subsequent winters dropped in spring weights comparable to that of the cows which were on the moderate level during the entire trial.

The low level appears to be sub-optimum during the first four winters' of the cow's life. Beyond this point of maturity, however, this level has produced levels of productivity, expressed as pounds of calf weaned per cow, that are comparable to the moderate and high levels. A rate of development comparable to the moderate and high levels during the first four winters appears to be more desirable than either the low or very high levels practiced in this test.

The amounts of supplemental feed required for the various levels each winter are shown in Table 2. The supplemental feed provided the low level cows was fed typically from early January to mid-April.

The other groups received supplemental feed from early November to mid-April each year.

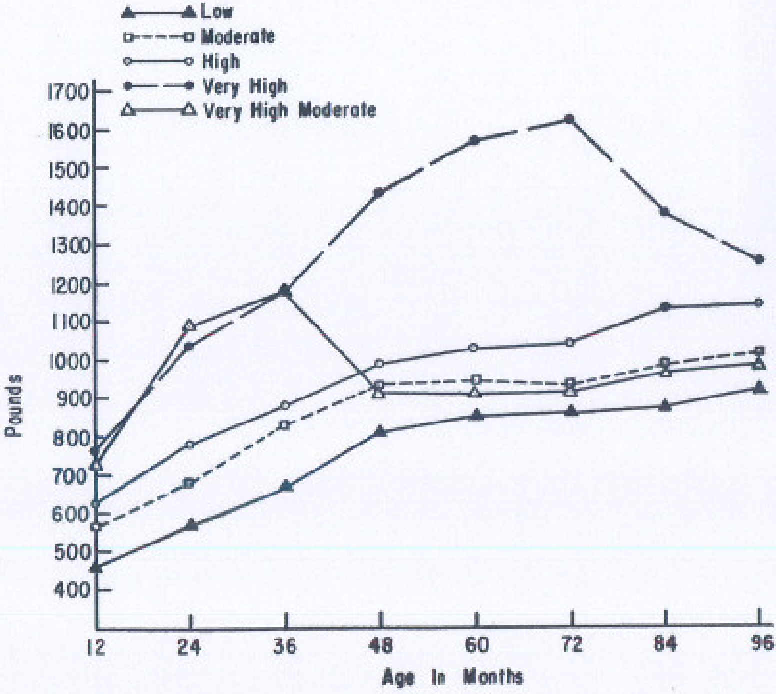

Figure 1. Average spring cow weights observed in mid April.

Table 2. Supplemental feed provided per cow for each level of wintering during the eight successive wintering periods.

	Low[1]		Moderate[2]		High[2]		VH[2] Mixed		VHM[2] Mixed	
Winter	CSC[4]	Milo	CSC	Milo	CSC	Milo	Ration		Ration	
'58-'59	52	39	275	259	389	732	3428		3428	
'59-'60	59	36	310	136	356	640	4990		4990	
'60-'61	55		238	81	396	753	5160		5160	
									CSC	Milo
'61-'62	38		225	29	389	643	6951		202	56
'62-'63	61		255	29	255	635	6154		249	--
'63-'64	80		258	34	242	569	6371		262	62
							CSC	Milo[3]		
'64-'65	61		236	--	291	699	224	672	252	--
'65-'66	41		208	--	247	576	270	1050	213	--

[1] Supplemental feeds provided during a period of approximately 100 days from early January.
[2] Supplemental feeds provided during a period of approximately 150 days from mid-November.
[3] The cows on the very high level received 867 lb. of mixed ration during the first month of the seventh winter.
[4] CSC represents cottonseed cake.

Survival

The data in Table 3 reveals the number of cows remaining after seven calf crops, the percentage remaining in the herd and the reasons for removal. Cows were culled from the herd on the basis of health or failure to conceive for two successive years. Percentage of cows remaining in the herd suggests cows on the high and very high levels are exhibiting

Table 3. Reasons for removal of beef cows wintered at different levels through seven calf crops.

Lot No.	1	2	3	4	5
Winter Level	Low	Moderate	High	Very High	Very High to Fourth Winter then Moderate
No. of Heifers started on test as weaner calves (1957-58)	30	30	30	15 (30)[1]	15
No. of cows remaining	25	26	24	11 (23)	12
Percent of cows remaining.	83.4	86.7	80.0	73.3 (76.6)	80.0
Cause for Removal:					
Death					
Calving Difficulty	1			3	
Impaction of Abomasum	1				
Brain Abcess		2			
Uterine Infection		1			
Cause Unknown	1		2		
Culled					
Open 2 Successive Years	1		4		1
Hardware Disease		1			
Poor Condition	1				
Cancer Eye					1
Foundered					1
Uterine Prolapse				1	
Total	5	4	6	4	3

[1] Number in parenthesis represents average of the two groups.

lower survival rates than those on the low and moderate levels. This effect is most pronounced in the case of those females developed at the highest level.

Productivity

Productivity of the beef cow involves both percentage calf crop and weaning weight of the calves produced. Weaning weight, taken at a given time, is a reflection of birth date, milk production and the calves ability to grow on the milk and other feeds consumed. Table 4 summarizes the long term performance of the cows in the different treatment groups. It is apparent that each higher level of wintering from low to high has tended to result in earlier calving dates by about one week. The very high level does not appear to have improved this particular characteristic.

A graphic representation of the influence of level of wintering on calving dates for each calf crop is shown in Figure 2. The differences appear to be rather consistent for the low, moderate and high levels for the first four calf crops, however, the widest differences occur in the case of the second calf crop. Level of winter feed appeared to have no consistent effect upon calving date after the fourth calf crop. The long term average birth weight of calves produced by the different groups does not vary widely. The greatest differences observed in birth weights were for the first calf produced by cows on the low level which averaged

Table 4. Performance of cows wintered at different levels through seven calf crops.

	1 Low	2 Moderate	3 High	4 Very High	5 VHM
No. of heifers started on test (1957-59)	30	30	30	15	15
No. of cows remaining after seven calf crops	25	26	24	11	12
Average calving date (Month/day)	3/14	3/9	3/2	3/5	3/4
Average birth wt., lbs.	75	77	79	75	77
Percent calf crop weaned per cow herd	86.3	88.3	85.9	83.7	85.7
Total lbs. calf weaned					
Non-corrected	67,105	78,135	73,710	33,190	36,685
Sex corrected	68,789	80,509	65,642	34,078	37,697
Age and sex corrected	69,546	79,410	73,616	33,461	36,956
Average lbs. of calf weaned					
Non-corrected	427	457	482	449	448
Sex corrected	438	471	495	461	460
Age and sex corrected	442	465	481	452	451
Average milk production (lbs. daily)	11.2	12.7	12.1	10.6	10.2
Total supplement cost for the seven wintering periods ($ per cow)	19.53	92.31	207.28	741.26	308.23

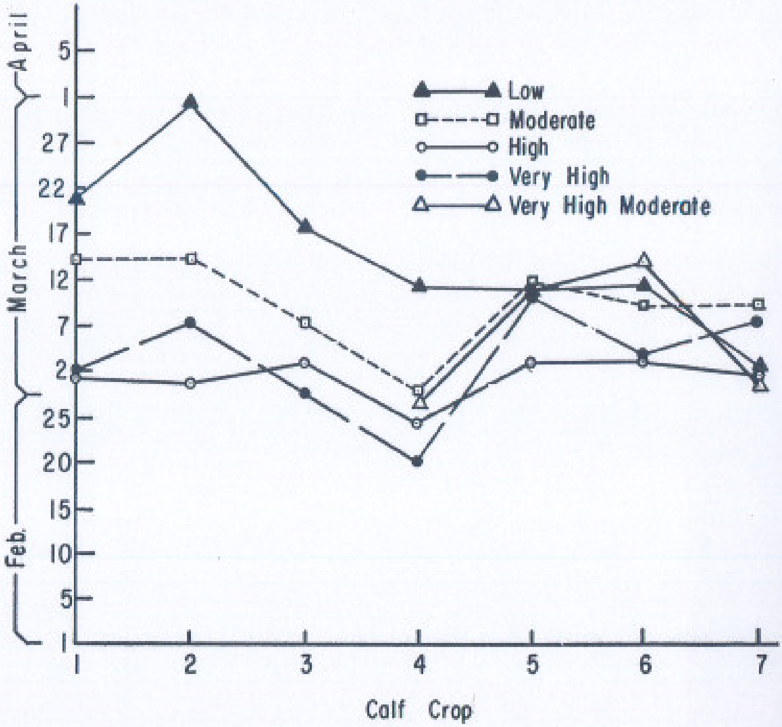

Figure 2. Influence of level of wintering on average birth date for successive calf crops.

about 10 lbs. less than calves produced by the other groups. After the first calf very slight differences appeared in birth weight among the various treatment groups.

The average weaning weights of calves for seven calf crops (Table 4) increase progressively from the low to high level. Weaning weights of calves produced by heifers developed at the very high level are intermediate with respect to those observed for the low and moderate treatments. Figure 3 shows graphically the performance for all groups of cows in this regard with marked difference occurring in the first two calf crops. However, the difference narrows considerably beyond this point. It is interesting to observe that the females developed at the low and moderate levels have improved steadily throughout the period. However, heifers developed at the high and very high levels appear to reach a peak in pounds of calf weaned at the second calf crop and more or less maintain this level.

It is also of interest to note that the females developed at the very high level produced calf weights as high in the case of the second calf as was noted for the same heifers for the 3rd and 4th calf, while all other

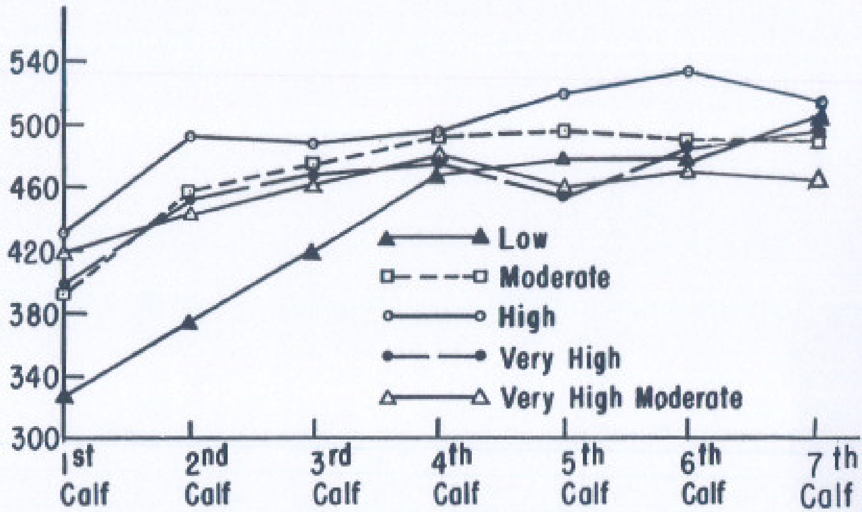

Figure 3. Average weaning weights (corrected for sex) of successive calf crops produced by cows wintered at different levels.

females exhibited a rather steady improvement in weaning weight to the 4th calf. This may suggest that age of dam correction factors that are commonly used in selection programs may or may not be correct depending on the level of heifer development practiced.

Figure 4 shows the pounds of calf weaned per cow remaining in the herd at a given breeding season. This reflects both percentage calf crop and weaning weight of the calves produced. From this the low level has a most pronounced depressing influence through the first three calf crops after which time performance is comparable to the moderate and high levels. The higher productivity associated with the high level as compared with the moderate appears to diminish at a consistent rate through the first 4 calf crops, however, differences observed after the third calf are small.

The cost of supplementation for the various groups is also shown in Figure 4. Since the value of weaned weight is highly variable no attempt has been made to outline the single most profitable program, however, the feed costs reported or those that might be assigned by a producer and the comparative weaning weight and value per cow might be used to assess the value returned for increasing investments in feed. On this basis it would appear that returns for supplemental feed are most likely to favor the moderate level over the low level during the winters preceeding the second and third calf crops. Beyond this point in maturity of the cow, the weight change pattern characteristic of the low level appears most likely to result in greatest return above feed cost.

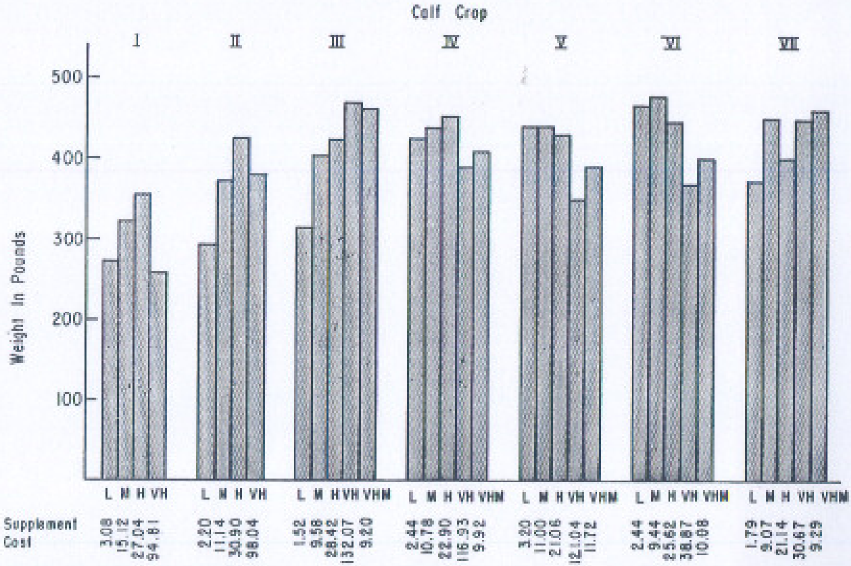

Figure 4. Influence of level of wintering on pounds of calf weaned per cow and supplemental feed cost prior to each calf crop.

Summary

The influence of level of wintering on the performance of beef females through the first seven calf crops is reported. The most marked sustained influence of the low level of wintering appears to be reflected in average calving date. The weight change pattern exhibited by the moderate level appears to be consistent with both productivity and economy of wintering. The weight change characteristic of this level was a gain of 97 lbs. the first winter as weaner calves with subsequent winter weight losses of approximately 10-15 percent from fall weight including calving loss. Differences in cow survival resulting from level of wintering are not conclusive at this point but the trend favors the moderate level. Development and maintenance of the beef females at a very high level reduced productivity below that observed for the more moderate levels. The results obtained by switching cows from a very high to moderate level indicates that the damage to milk producing ability occurs early in life and is not corrected by lower levels after the third winter. Percentage calf crop was, however, improved by this treatment.

The data presented for the individual yearly calf crops indicate that rather than select a level of wintering for the life time of the cow, consideration should be given to the life cycle feeding approach in which higher levels are used during growth and development of the female followed by lower levels after the cow has reached maturity since the major influence of the various levels on cow productivity occurs during the first three calf crops.

Supplemental Winter Feeding of Spring Calving Beef Cows on Bermudagrass Pasture

J. E. McCroskey, Frank Bates, Robert Renbarger and W. C. Elder

Over the past ten years bermudagrass has received considerable attention as a pasture forage for beef cattle. Acreage has increased in some areas of the state to the point that it is now considered a major forage and is being used as a year-round pasture. Research in Oklahoma and surrounding states has been rather extensive on such matters as variety, level of fertilization, stocking rates and forage yield per acre. Most of the work has been concerned with production during the growing season and very little data are available on cattle performance or supplemental feed requirements during the winter months.

Since Oklahoma is primarily a "cow-calf" state most of the bermudagrass pastures in the state are used by cows rather than steers. It has been established that cows grazing native grass pastures during the winter months need additional protein and sometimes a supplemental energy source. The amounts needed vary with location, quality and amount of grass and condition of cattle. It is reasonable to assume that cattle grazing bermudagrass during the dormant season also need some type of supplemental feed. A pilot trial was conducted at Heavener and Perkins in cooperation with the Agronomy Department comparing milo grain with cottonseed meal as a winter supplement for spring-calving cows. Results of the two-year study indicated a definite advantage for cottonseed meal. Chemical analyses of the grass and digestibility studies also indicate a need for a high-protein supplement during the winter months.

The current study was initiated in the fall of 1965 at the Ft. Reno Experiment Station to determine the level of protein supplement needed during the winter months by spring-calving beef cows grazing Midland Bermudagrass year-long. A comparison was also made to determine the need for supplemental phosphorus during the winter.

Procedure

Sixty-four grade Hereford cows, ranging in age from three to four years, were selected from the Experiment Station herd and divided into four lots of sixteen on the basis of age, weight and previous treatment. All cows were bred to calve during the months of January through April. Three of the lots (1, 2 and 3) grazed a 140 acre pasture of Midland Bermudagrass while one lot (4) was used as a control and grazed an adjacent 140 acre native grass pasture. Lots 1, 2 and 3 received one, two and three pounds of cottonseed meal (41 percent C.P.) per head daily, respectively. Lot 4 cows were fed two pounds of cottonseed meal (41 percent C.P.) per head daily. This is the level which has been shown to be adequate for spring-calving cows on native grass pastures at Ft. Reno.

Work done in cooperation with ARS USDA.

One-half of the cows in lots 1, 2 and 3 were fed additional phosphorus in the form of monosodium phosphate (36 gm./head/day) in the cottonseed meal supplement. All cows on bermudagrass were fed salt free-choice. Lot 4 was fed a mineral mixture of salt and bonemeal (2:1) free-choice.

All lots on bermudagrass grazed a common pasture and were fed their supplements in individual stalls once daily, while cows on native grass (lot 4) were group-fed. All cows were injected with 1,000,000 I.U. of vitamin A early in January, 1966.

The bermudagrass pasture was cross-fenced into four equal pastures to facilitate rotational grazing. Cows were allowed to graze each pasture for approximately a week then were moved to another. It was necessary to mow the pastures occasionally to prevent spot grazing and to use a drag to scatter manure piles. Two hundred pounds of nitrogen was applied per acre in three equal applications during the growing season.

Data were collected on cow weight changes (bi-weekly), calf birth weights, intermediate calf gains, weaning weights and milk production. Blood samples were taken from one-half of the cows in each treatment group at the start (December 3, 1965) and at the end of the winter (April 15, 1966) to study the changes in plasma phosphorus content.

Milk production was estimated by weighing the calf prior to and after nursing following a 12-hour period away from the cow. The sum of two successive 12-hour periods was used to estimate 24-hour milk production. Milk production data were obtained six times during the nursing period.

Results and Discussion

The effects of level of winter protein supplement (cottonseed meal) on cow and calf performance are shown in Table 1. Postcalving weight losses of cows grazing bermudagrass diminished with each one-pound increase in winter supplement. Cows on native grass receiving two pounds of cottonseed meal had similar postcalving loss in weight to those grazing bermudagrass and consuming three pounds of supplement. When postcalving weight loss is expressed as a percent of the initial winter weight it can be seen that the cows receiving the least amount of winter supplement on bermudagrass lost a higher percent of body weight (lots 1, 2 and 3). The percentage weight loss of cows grazing native grass was similar to lot 3. All are within the "safety zone" of winter weight loss which has been established in previous wintering studies on native grass at Ft. Reno. At weaning all lots were similar in body weight and were heavier than at the start of the previous winter, indicating that winter weight losses were not excessive and that grass was adequate during the growing season to allow for restoration of body tissues.

Average 24-hour milk production of cows grazing bermudagrass was greater with each increment of cottonseed meal. Cows grazing

Table 1. Effect of Level of Protein Supplement on Cow and Calf Performance

Pasture	Bermuda	Bermuda	Bermuda	Native
Lot No.	1	2	3	4
Level of C.S.M. (lb.)	1	2	3	2
No. of Cows	16	16	16	16
Cow Data:				
Initial wt. (lb.)	1088	1090	1105	1066
Wt. change from initial (lb.)				
to post calving	—130	—118	—100	—101
to weaning	+ 25	+ 30	+ 88	+ 39
Postcalving wt. loss (% of initial)	12.0	10.9	9.0	9.4
Ave. 24-hr. milk (lb.)	12.5	13.0	14.1	13.7
Calf Data:				
Ave. birth wt. (lb.)	74	85	79	73
Ave. weaning wt. (lb.)[1]	476	487	489	444

[1] Weaning weights adjusted to 205-day steer equivalents.

native grass (lot 4) were intermediate in milk production between lots 2 and 3 on bermudagrass. Figure 1 shows the pattern of milk production for all four lots during the nursing period. It is interesting to note that the cows grazing bermudagrass (lots 1, 2 and 3) ranked in the same order at each milk sampling date. Lot 4 cows were more variable in milk production than the other three lots but had a higher average production than both lots 1 and 2. It is surprising that the differences in milk production between treatment groups on bermudagrass are rather small when we consider the relative differences in amounts of supplement fed. If we use lot 4 as a control it appears that between two and three pounds of cottonseed meal are needed for cows grazing bermudagrass to equal the milk production obtained on native grass with two pounds of supplement.

Level of cottonseed meal fed during the winter had no consistent effect upon calf birth weight but weaning weights increased slightly with level of supplement (Table 1). Although cows fed one pound of cottonseed meal (lot 1) weaned lighter calves than the other lots on bermudagrass, they still weaned heavier calves than those on native grass fed two pounds of supplement (lot 4). This is not consistent with the milk production data obtained if we assume calf gains are directly correlated with milk produced. However, it has been shown that calf gains and milk production of the dam are highly correlated only through the first four months of lactation. Therefore, a major portion of the nutrient intake by the calves probably came from grass during the last three months. A possible explanation for the low weaning weights of calves from cows grazing native grass lies in the fact that they had no shade during the summer months, while those on bermudagrass did.

Phosphorus supplementation results are shown in Table 2. The data indicate that additional phosphorus was beneficial at both the one

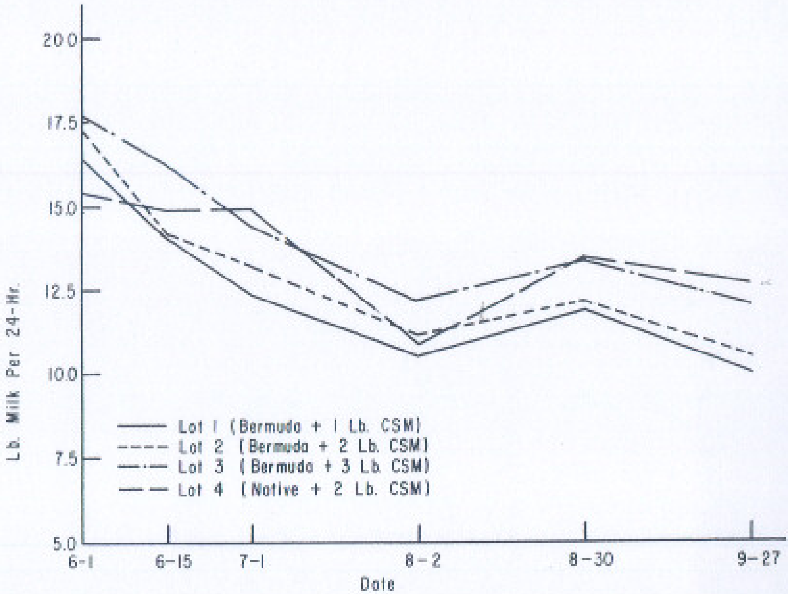

Figure 1. Effect of level of protein supplement on milk production.

and two pound levels (lots 1 and 2) of cottonseed meal but not at the three pound level (lot 3). Cows in lots 1 and 2 receiving supplemental phosphorus lost less weight through calving and were heavier at weaning than cows on the same level of supplemental protein without additional phosphorus. Milk production and calf birth weights were not improved by additional phosphorus but there was a slight increase in calf weaning weight as a result of phosphorus supplementation in lots 1 and 2. As would be expected, the greatest effect of phosphorus supplementation was observed with cows fed only one pound of cottonseed meal (lot 1).

Table 3 shows the plasma phosphorus content of cows grazing bermudagrass at the start and end of the wintering period. Apparently, three pounds of cottonseed meal along with the pasture provides adequate phosphorus to meet the requirements of the cow during gestation. Although the phosphorus levels are quite variable there is an indication that plasma level of phosphorus was improved on the low level of cottonseed meal by feeding additional phosphorus. It should be pointed out that some workers feel that a level of 4.0 mg. phosphorus per 100 ml. blood plasma is adequate. Therefore, it would appear that even the lowest level of cottonseed meal did not result in abnormally low plasma levels of phosphorus. It must be recognized, however, that calcium and phosphorus are mobilized from the skelton during periods of inadequate dietary intake. Thus, it is quite likely that the cows on the lowest level of intake were drawing on their reserves in order to maintain a normal level in the blood.

Table 2. Effect of Supplemental Phosphorus on the Performance of Cows and Calves Grazing Midland Bermudagrass

Lot No.	1		2		3	
Phosphorus supplement No. of Cows	0 8	+ 8	0 8	+ 8	0 8	+ 8
Cow Data:						
Initial wt. (lb.)	1102	1073	1084	1096	1093	1117
Wt. chg. from initial (lb.)						
to postcalving	—137	—123	—129	—107	— 99	—101
to weaning	— 6	+ 43	+ 35	+ 25	+ 89	+ 86
Postcalving wt. loss (% of initial)	12.4	11.5	11.9	9.8	9.1	9.0
Ave. 24-hr. milk (lb.)	12.0	12.3	15.1	13.0	13.8	13.5
Calf Data:						
Ave. birth wt. (lb.)	75.6	73.0	80.1	89.1	83.1	75.4
Ave. weaning wt. (lb.)[1]	471	481	483	490	500	478

[1] Weaning weights adjusted to 205-day steer equivalents.

Although these data indicate only a slight advantage to phosphorus supplementation, it is a good practice to provide a mineral mixture containing phosphorus at all times, especially during the winter months.

Summary

Sixty-four mature grade Hereford cows were allotted into four equal groups to determine the level of winter protein supplement required by spring-calving cows grazing Midland Bermudagrass year-round. One group (lot 4) was used as a control and grazed an adjacent native grass pasture and was fed according to established requirements for cows grazing native grass pasture at Ft. Reno during the winter (2 lb. C.S.M./hd./day). One-half of each lot of cows grazing bermudagrass was fed additional phosphorus (36 gm. monosodium phosphate/hd./day) to study the need for supplemental phosphorus by cows grazing Midland Bermudagrass.

The data show that cow weight changes, milk production and calf weaning weights were improved with each one-pound increase in cottonseed meal up to three pounds. It appears that between two and three pounds of cottonseed meal may be needed by cows grazing bermudagrass to accomplish the same cow weight changes and milk production obtained on native grass under recommended feeding conditions. However, calf weaning weights were higher for cows wintered on bermudagrass and one pound of cottonseed meal than for those on native grass and two pounds of supplement. Low weaning weights on native grass may have been due to the extremely hot summer and the lack of shade.

Supplemental phosphorus appeared to improve cow and calf performance for the lots fed one and two pounds of cottonseed meal per

Table 3. Effect of Supplemental Phosphorus on Plasma Phosphorus of Cows Grazing Midland Bermudagrass

Lot No.	1		2		3	
Phosphorus supplement[1]	0	+	0	+	0	+
No. of Cows	4	4	4	4	4	4
Plasma Phosphorus (mg./100 ml.)						
12-3-65	5.9	5.5	4.7	5.6	5.3	6.0
4-15-66	4.1	6.5	5.3	5.9	4.0	4.5
Ave. change	—1.8	+1.0	+0.6	+0.3	—1.3	—1.5

[1] One-half of each lot received no supplemental phosphorus, while the other half received 36 gm. monosodium phosphate (7.2 gm. phosphorus) per head daily during the winter.

head daily but had no apparent beneficial effect on the lot fed three pounds of supplement. Although blood phosphorus levels were quite variable, it appeared that there was an improvement in phosphorus level of the plasma of cows fed one pound of cottonseed meal when additional phosphorus was provided.

Results of this one-year study suggest that two pounds of cottonseed meal as a winter supplement is adequate for satisfactory performance of mature spring-calving beef cows grazing Midland Bermudagrass year-round. The data also suggest the need for supplemental phosphorus during the winter months, especially if low levels of protein supplement are fed.

Influence of Mature Cow Size on Feed and Energy Requirements

S. A. Ewing, Larry Smithson, Craig Ludwig, and D. F. Stephens

One of the more frequent questions asked about production efficiency in the beef cattle business deals with the influence of cow size on feed requirements. The question concerning optimum cow size is complex, however, one bit of information of importance in arriving at an answer concerns the amount of additional feed, largely energy, to support increasing increments of cow weight.

This serves as a progress report on a two year study underway at this station to study the influence of cow size on energy requirements to support the cow unit. A more complete analysis will be published upon termination of the second trial which is presently being completed.

Procedure

Twenty mature, commercial Hereford cows were selected from a large Oklahoma ranch to serve as experimental animals. The cows selected were 6 to 7 years of age and ranged in weight from approximately 900 lbs. to 1500 lbs. Degree of fatness was estimated by measuring fat cover at the 12th rib with a thermister probe. Fat cover per 100 lbs. of shrunk live weight was similar for the group of medium size cows (averaging about 1000 lbs.) and the large cows (averaging about 1400 lbs.). The cows were confined in dry lot at the Ft. Reno station and fed individually during the experimental period which encompassed a calendar year from just ahead of calving until the next calf was dropped. The cows were weighed at weekly intervals and the feed adjusted periodically to foster a desirable individual weight change pattern throughout the lactation and dry periods. A mixed ration containing 60 percent TDN was fed during the lactation period and a similar ration containing 50 percent TDN was fed during the dry period. Numerous body measurements were collected and will be reported when the second trial is completed. During the lactation period the calves ran with the cows except during the feeding period each day. The calves were given individual access to a mixture of chopped alfalfa hay and 5 percent molasses.

Milk production was measured at 28 day intervals throughout the lactation period and milk samples were taken for fat analysis to permit the expression of energy requirement for the cow on a milk corrected basis.

Digestible energy content of the ration fed was determined by the chromic oxide reference technique. When the two year study is completed, final data will be presented on a digestible energy as well as

established commercial herd.

Appreciation is extended to The American Hereford Association, Kansas City, Missouri, for providing grant funds to partially support this work. Appreciation is also extended to Codding Cattle Research, Foraker, Oklahoma, for permitting selection of experimental animals from their

TDN basis. In this report the energy requirements will be expressed on the basis of TDN values.

The weight change patterns during the lactation and dry periods were predetermined based on initial weight and were carefully controlled to restore the initial pre-calving weight just ahead of the next calving.

Results and Discussion

The data from this trial resulted in the following equation for predicting the annual energy requirement to support the cow exclusive of that required for milk production.

$$\text{Annual TDN Requirement (lbs.)} = 16.31\ \text{Weight}^{0.74}$$

The annual requirements predicted by the above equation for cows of different mature weights are shown in Table 1.

From the data in Table 1, the energy requirement to support the cow, exclusive of milk production, increases at a rate of 7 percent for each 100 lb. increment in cow weight.

In order to estimate the cow-calf unit efficiency the energy consumed by the calf in the form of milk and other feeds must be superimposed on the requirement to support the cow. For example a 1000 lb. cow would require about 2710 lbs. of TDN for her support plus another 810 lbs. to produce 15 lbs. of 3 percent milk daily during a 205 day lactation. For the calf to wean at 475 lbs., an additional 643 lbs. of TDN would be required above that supplied by the milk consumed. On this basis the annual TDN requirement for the cow-calf unit would be 4163 lbs. This would result in a TDN efficiency value of 876 lbs. of TDN per 100 lbs. of weaned weight. Had the calf weaned heavier, added TDN would have been required in production but efficiency would have improved.

Through calculations of this type it is possible to estimate the added calf weight needed to support the additional TDN required by the

Table 1. Influence of Cow Size on Annual TDN Requirements to Support the Cow Including a Desirable Weight Change Pattern

Cow Weight (Lbs.)	Annual TDN Required (Lbs.)	Requirement as % of 100 lb. Cow
900	2503	93
1000	2709	100
1100	2904	107
1200	3098	114
1300	3286	121
1400	3472	128
1500	3653	135
1600	3832	142

larger cow and the larger calf so that TDN efficiency is similar for cow-calf units involving cows of different weights. This involves the use of the prediction equation for the cow requirement and the TDN requirements of the calf for maintenance and production. On this basis the TDN efficiency of a 1000 lb. cow weaning a 475 lb. calf can be established as a base point for TDN efficiency. Then the efficiency of the larger cow can be calculated at different calf weaning weights. This can be plotted and the improving efficiency of heavier weaning weights will intersect the efficiency line of the base point cow-calf unit.

By calculations of this type it is estimated that the weaning weights shown in Table 2 would be required of cows of different weights in order to have equal TDN efficiency for the unit.

The following formula is proposed as a method of indexing cows of different size for production efficiency.

$$\text{Cow Efficiency Index} = \frac{\text{205 day adjusted calf wt.} \times 100}{\text{Mature cow weight}^{0.74}}$$

This formula involves calf weight and cow weight to the 0.74 power. Table 3 illustrates the use of the index.

All cows in this example index the same. If the 1200 lb. cow had weaned a calf at 500 lbs. then the resulting index would be 263 rather than 286. As a result this cow would have been less efficient in the production of calf weight than the 1000 pound cow weaning a 475 pound calf.

Table 2. Calf Weaning Weights Required of Cows of Different Weights to Result in Equal TDN Efficiency

Cow Weight (lbs.)	Necessary Weaning Wt. (lbs.)	Calf Weaning Weight as a % of Cow Wt.
1000	475	47.5
1200	543	45.3
1400	609	43.5
1600	672	42.0

Table 3. Efficiency Index for Cow Efficiency

Cow Weight lbs.	Cow Weight$^{0.74}$ lbs.	Calf Weight lbs.	Efficiency Index
1000	166.1	475	286
1200	190.0	543	286
1400	212.9	609	286
1600	235.0	672	286

It should be recognized that calf weight required to result in equal TDN efficiency may not be the same as the added calf weight required to support the cost of additional TDN. These relationships depend on the cost estimates on the TDN utilized, weaning weight value and percentage calf crop which influences the pounds of calf weaned per cow.

Table 4 provides values for cow weights to the 0.74 power for use in the equation for indexing cow efficiency.

Table 4. Cow Weights$^{0.74}$

Cow Wt (lbs.)	Cow Wt.$^{0.74}$ (lbs.)	Cow Wt (lbs.)	Cow Wt.$^{0.74}$ (lbs.)
900	153.5	1350	207.2
950	159.7	1400	212.9
1000	166.1	1450	218.6
1050	172.0	1500	224.0
1100	178.1	1550	229.5
1150	184.0	1600	235.0
1200	190.0	1650	240.4
1250	195.8	1700	245.8
1300	201.5		

Summary

Twenty commercial Hereford cows were used to study the relationship between cow size and energy requirements. An equation is presented for predicting the annual energy requirement of cows of different weights. A formula for indexing cow efficiency is proposed.

The Influence of Stilbestrol Implants on the Performance of Calves on Wheat Pasture or Sorghum Silage

S. A. Ewing, Gale Thompson and Robert Renbarger

The influence of stilbestrol on the performance and efficiency of finishing cattle is well recognized. In addition, several tests have shown gain stimulation in stocker cattle grazing good improved pastures. Little information is available, however, as to the gain stimulation that might be expected in calves grazing wheat pasture. Since this type of forage program is of great importance to Oklahoma it was deemed desirable to test the influence of stilbestrol implants on calves grazing this type of pasture or consuming other roughages in a stocker program.

Procedure

The test involved forty head of weaner heifer calves weighing approximately 470 lbs. Due to a shortage of wheat pasture the original experimental plan was changed so that one half of the heifers were maintained on wheat pasture and one half on sorghum silage. One half of each of these groups were allotted to receive supplemental energy feed in the form of a mixed ration consisting of 77 percent ground milo, 8 percent molasses and 15 percent chopped alfalfa hay. This plan resulted in four major treatment groups as follows.

1. Sorghum silage
2. Sorghum silage + Supplemental energy feed
3. Wheat pasture
4. Wheat pasture + Supplemental energy feed

Within each major treatment group one half of the calves were selected at random to receive a 12 milligram stilbestrol implant at the beginning of the test. Initial and final weights were determined after a 12 hour shrink without feed and water. Since wheat pasture was in short supply the stocking rate this particular year was approximately 4.8 acres per head which is considerably below the normal expected carrying capacity in the area used in these studies.

Results

The average responses to stilbestrol and supplemental energy feed for calves consuming silage or wheat pasture as the major source of roughage are summarized in Table 1. The total gain advantage, during the 88 day test period, for supplemental energy feed was 70 lbs.

The average total gain response from stilbestrol implants during the 88 day test, among all major treatment groups, was 23 pounds or an increase in daily gain of 0.26 lbs. daily. The average daily gain for all implanted cattle was 2.10 pounds as compared with 1.84 for the unimplanted controls. The percentage gain response associated with stilbestrol treatment was 14.1 percent.

Table 1. Response of Stocker Heifer Calves to Stilbestrol Implants

	No supplemental energy feed		Supplemental energy feed[1]	
	Control	Implant	Control	Implant
No. of heifers	10	10	10	10
Initial wt. (12-8-66), lbs.	481	463	473	477
Final wt. (3-10-67), lbs.	609	611	669	698
Total gain (88 days), lbs.	128	148	196	221
Gain advantage over controls, lbs.		20		25
Daily gain, lbs.	1.45	1.69	2.23	2.51
Daily gain advantage over controls, lbs.		.24		.28

[1] Calves had access to supplemental energy feed consisting of 77 percent ground milo, 8 percent molasses and 15 percent chopped alfalfa hay.

Table 2 summarizes the response to stilbestrol within the four major treatment groups. Faster gains were associated with stilbestrol treatment in three of the four groups. The reason for failure to observe a response to stilbestrol in the group of cattle on wheat pasture with supplemental grain is not clear, however, sample size within single major treatment groups is small. The low rate of gain in one stilbestrol treated animal in this particular treatment group had a marked influence on the results. Other than the low rate of gain there was no apparent reason for excluding the data collected on this animal, therefore, these observations remain in the data as summarized.

Table 2. Response of Stocker Heifer Calves to Stilbestrol Implants

	Sorghum Silage + Protein Supplement[1]	Sorghum Silage + Supplemental Ration[2]	Wheat Pasture	Wheat Pasture + Supplemental Ration[3]
No. of heifers	10	10	10	10
Initial wt. (12-8-66), lbs.	472	474	471	477
Final wt. (3-10-67), lbs.	553	667	667	701
Total gain (88 days), lbs.	81	193	196	224
Daily gain, lbs.	.92	2.19	2.22	2.54
Daily gain:				
Controls	.87	1.87	2.03	2.58
Stilbestrol implant[4]	.95	2.50	2.42	2.51
Daily supplemental feeds[1-3]				
Mixed feed	---	9.64	---	9.34
Cottonseed meal	1.50	1.00	---	---
Mineral & salt	Free Choice	Free Choice	Free Choice	Free Choice

[1] 1.5 lbs. cottonseed meal daily.

[2] Supplemental ration consisting of 77 percent ground milo, 8 percent molasses and 15 percent chopped alfalfa hay fed at a level consumed by cattle on wheat pasture when provided free choice plus 1.0 lb. cottonseed meal daily as supplemental protein.

[3] Supplemental ration described in footnote 2 provided free choice. No additional protein supplement was fed.

[4] Implanted with 12 milligram Stimplant (Pfizer).

Summary

Forty weaner Hereford heifer calves were utilized to evaluate the response of heifers consuming sorghum silage or wheat pasture to 12 milligram stilbestrol implants. An additional 23 pounds of gain during the 88 day experimental period was associated with stilbestrol implantation. The improvement in daily rate of gain was 0.26 pounds daily or 14 percent. Based on this data it would appear that implantation could be profitable when the feed supply available is likely to produce 0.90 pounds or more daily gain.

Methods of Processing Milo for Fattening Cattle*

Robert Totusek, Larry Franks, Willie Basler, and Robert Renbarger

Milo (sorghum grain) is the most readily available and cheapest grain in many cattle feeding areas. The production of milo and its use as a livestock feed have tripled during the past 10 years. It will be fed in even greater quantity in the future.

However, there are some problems associated with the feeding of milo to fattening cattle. It is very variable in composition and feeding value, and lower in feeding value on the average than other feed grains. The lower feeding value seems to be due to a lower protein digestibility and a lower starch availability compared to corn and barley. The availability of starch is especially important, since starch comprises 70-75 percent of milo grain, and milo is included in the ration primarily as a source of energy. Some fattening rations today contain as much as 90 percent or more milo, so starch obviously makes up a large portion of the ration, and any change in starch availability has a direct and large influence on total ration efficiency.

Processing offers one means of altering starch availability. In the past milo has most commonly been coarsely ground, dry rolled, or steam rolled ("conventional" steam rolling, with short time exposure to steam). Considerable research at this station and elsewhere has indicated very little difference in feeding value of milo processed by these three methods.

Previous work at this station showed that pelleting milo improved its utilization 5 to 9 percent, but lowered carcass grade and dressing percent were rather consistently observed. The high cost of pelleting is a further and major deterant to its use. Previous work at this station has likewise indicated a 5 percent improvement in feed efficiency due to fine grinding of milo, compared to coarse grinding. However, fine grinding may present a problem with dust and "fines", and does not have a desirable texture in the opinion of many cattle feeders.

Two new methods of processing appear very promising. Research at the Kansas and Texas Stations has indicated a sizeable improvement in dry matter utilization due to high moisture (25-35 precent) harvesting of milo. A possible improvement has also been suggested from the reconstituting of milo (adding water to "dry" milo to raise the moisture level to about 30 percent, and subsequent fermentation with exclusion of air).

Work at the Arizona Station has indicated a 4 percent or greater improvement in feed efficiency, along with greater feed intake and faster gain, from the partial cooking of milo followed by "flaking" through a

*The cooperation of the Harris Packing Company, Oklahoma City, Oklahoma, in slaughtering the cattle and collection of slaughter and carcass data is gratefully acknowledged. Thanks are also extended to S. A. Ewing for making cattle from another project available, to personnel at Ft. Reno for assistance in the conduct of the experiment and collection of data, and to James Newsom and Vincent Neuhaus for the statistical analysis.

roller mill. The milo was partially cooked by exposure to steam for 20-25 minutes. Research at the California Station has indicated an occasional but inconsistent response from the pressure cooking of grain followed by flaking. The objective of this experiment was to compare five methods of processing milo.

Procedure

Forty-five Hereford steer calves with an average weight of 494 lbs. and an average age of 9 months were obtained from the Experiment Station herds. They were divided into three groups of 15 head each, and randomly allotted within each weight group into 5 pens of 3 steers each. The 5 pens within each group (replication) were fed milo processed by 5 different methods, along with a basal ration.

The basal ration was fed at a level to just meet the maintenance requirement of the steers, so that the gain of the steers could be attributed to milo. The basal ration was composed of (percent): chopped alfalfa, 35.0; cottonseed hulls, 23.0; cottonseed meal, 40.0; salt 1.0; and dicalcium phosphate, 1.0. Vitamin A was added at a level of 2000 I.U. per lb. of basal, and chlortetracycline was added at a level to result in an intake of approximately 75 mg. per steer daily. No hormones were fed or injected.

Milo was full-fed in addition to the basal. Processing methods which were compared were coarse grinding, fine grinding, reconstituting-rolling, steam process-flaking, and reconstituting-steam process-rolling.

Coarsely and finely ground milo were produced with a hammer mill, using 3/16 and ⅛ inch screens, respectively. Reconstituted milo was produced in 2 metal tanks with a capacity of 5000 lb. each. Milo in the tank was soaked in water for 60 minutes, then covered with a 6 mil plastic sheet covered with sand to keep the plastic in close contact with the milo and exclude as much air as possible. Milo was allowed to remain in the tanks at least 20 days before being rolled and fed. Very little feed spoilage was observed and no refusal of the reconstituted milo occurred. The reconstituted milo had a pleasant silage-like odor.

Steam process-flaking was accomplished by using the procedure reported by Hale and co-workers at the Arizona Station. Milo was subjected to steam (produced by a steam generator) in an unpressurized steam chamber for 20 minutes, then rolled immediately. The maximum temperature reached during steaming averaged 206°F.

The reconstituted-steam-rolled milo was reconstituted as described above, then steam processed and rolled. Steaming did not exceed 10 minutes because longer steaming resulted in a product too wet and soft to roll satisfactorily. Maximum temperature within the steam chamber did not exceed 203°F.

Feeds were rolled daily, and feeding was done once daily in sufficient quantity to assure availability of feed until the next feeding.

Steers in each pen had access to an open sided shed and an outside lot, with water (warmed in winter) available at all times.

The feeding period started December 8, 1965 and lasted 171 days. Initial and final weights were taken after a 16 hour shrink with no feed and water. At the termination of the feeding trial the steers were slaughtered at the Harris Packing Company, Oklahoma City, and carcass data collected after a 48-hour chill.

Results

Note the effect of processing method on dry matter (100 % — % moisture), test weight per bushel (density) and particle size in Table 1. The air dry milo which was either coarsely or finely ground averaged approximately 13 percent moisture, while the reconstituting-rolling and steam process-flaking procedures increased moisture levels to 27 and 19 percent, respectively. The combination of reconstituting and steam process-rolling resulted in a moisture level of 31.3 percent.

All of the processing methods decreased the density of milo. Reconstituting-rolling, steam process-flaking, and reconstituting-steam process-rolling resulted in the greatest decreases in density, and there was little difference in the three processing methods in this regard. However, there was a big difference in the particle size of the three products. Steam process-flaking, compared to reconstituting-rolling, produced more large particles (flakes) and much less fine material. Steam process-rolling of the reconstituted milo resulted in a small increase in large particles but also a large increase in fines compared to reconstituting-rolling. The fine particles in either of the reconstituted products was very fluffy in nature, and this characteristic resulted in a test weight per bushel very similar to the "flaked" milo.

Table 1. Effect of Processing Method on Dry Matter, Weight Per Bushel and Particle Size of Milo.

	% Dry Matter	Lb. wt.[1] per bu.	% Remaining On Sieve Of Indicated Size, In Inches Diameter of Openings							% Remaining On 40 Mesh Sieve	% Passing Through 40 Mesh Sieve
			18/64	16/64	12/64	8/64	1/12	1/18	1/25		
Coarsely ground	87.0	47.9	0	0	0	2.4	9.1	22.4	20.4	22.3	23.4
Finely ground	87.7	44.4	0	0	0	0	1.6	14.4	22.1	27.4	34.5
Reconstituted-rolled	73.0	26.6	0	.2	17.6	40.3	16.8	7.9	3.8	5.6	7.8
Steam process-flaked	81.0	26.0	2.3	19.1	47.0	21.5	5.1	2.0	.9	1.0	1.1
Reconstituted-steam-rolled	68.7	25.1	2.0	8.3	28.3	20.6	9.1	7.9	5.6	8.9	9.3

[1]On 90 percent dry matter basis.

Feedlot performance is shown in Table 2, with a further summary showing the relationship of coarse grinding to the other processing methods in terms of rate of gain, feed intake, and feed efficiency in Table 3. Coarsely ground milo was used as the basis for comparison because through the years coarse grinding, dry rolling or steam rolling ("conventional") have been processing methods of choice of cattle feeders, and research has indicated very little difference among them from the standpoint of efficiency of utilization.

It is interesting to note that rates of gain in three instances were almost identical, while steers fed finely ground milo gained slightly faster and those fed stream process-flaked milo outgained all others. However, statistical analysis indicated no significant differences ($P<.05$) in the rates of gain.

Since all steers received a maintenance allowance of the basal ration, milo alone was considered with respect to intake and efficiency of utilization. Processing method had a significant ($P<.01$) influence on milo intake, as follows: steam process-flaking resulted in a higher intake than all other methods except coarse grinding, and coarse grinding resulted in a greater intake than reconstituting-steam rolling. Differences in other comparisons were not statistically significant ($P<.05$). Note in the summary shown in Table 3 that compared to coarse grinding, steam process-flaking resulted in an increased intake, while the other three methods resulted in decreased intakes.

Milo required per lb. of gain was significantly ($P<.05$) affected by processing method. Coarse grinding resulted in a higher requirement of milo per lb. of gain than all other processing methods except steam process-flaking. Feed conversion of the steam process-flaked milo was very similar to that of coarsely ground milo, but not statistically different than the other three methods. Note in the Table 3 summary that steam process-flaking did not result in much change in feed efficiency

Table 2. Feedlot Performance (171 Days, 9 Steers Per Treatment)

	Method of Processing Milo				
	Coarsely Ground	Finely Ground	Reconstituted	Steam Process-Flaked	Reconstituted-Steam-Rolled
Av. initial wt., lb.	501	490	489	498	491
Av. final wt., lb	916	911	907	948	904
Av. daily gain, lb.	2.43	2.51	2.44	2.63	2.42
Av. daily feed, lb.					
Milo[1]	10.58(ab)	9.80(bc)	9.81(bc)	11.29(a)	9.28(c)
Basal	8.69	8.56	8.51	8.80	8.49
Total	19.27	18.36	18.31	20.09	17.78
Feed/lb. gain, lb.					
Milo[2]	4.37(a)	3.93(b)	4.01(b)	4.30(ab)	3.85(b)
Basal	3.57	3.41	3.48	3.35	3.51
Total	7.92	7.32	7.49	7.64	7.35

[1] Any 2 averages without a common letter differ significantly ($P<.01$).

[2] Any 2 averages without a common letter differ significantly ($P<.05$).

Table 3. Summary of Effect of Milo Processing Method on Feedlot Performance.

	Coarsely Ground	% Change Compared to Coarsely Ground Milo: Finely Ground	Reconstituted	Steam Process-Flaked	Reconstituted-Steam-Rolled
	lb.				
Av. daily gain	2.43	+ 3.3	+ .4	+8.2	— .4
Av. daily feed	10.58	— 7.4	—7.3	+6.7	—12.3[2]
Milo/lb. gain	4.37	—10.1[1]	—8.2[1]	—1.6	—11.9[1]

[1] Significantly different ($P<.05$) than value for coarsely ground milo.
[2] Significantly different ($P<.01$) than value for coarsely ground milo.
For statistical difference between other pairs of values, see Table 2.

compared to coarse grinding, while the other three processing methods resulted in sizeable and rather similar improvements in efficiency.

Slaughter and carcass information is presented in Table 4. Values for most of the traits were very similar for all treatments, and none of the traits were significantly ($P<.05$) affected by processing method. The greater weight of calculi in the cattle fed steam process-flaked milo was interesting and will be observed further in subsequent tests. However, calculi differences were not statistically different, and no clinical cases of urinary calculi were observed in the steam process-flaked milo cattle. One case of urinary calculi occurred in a steer receiving finely ground milo on the 160th day of the experiment.

Discussion

Steam process-flaking resulted in an increased intake of milo and a faster rate of gain, compared to other processing methods. Even though some of the differences were not statistically significant, these trends are similar to those reported from other research and are probably real. In other words, steam process-flaking apparently improves the palatability and consequently the intake of milo, which results in an increased rate of gain. However, the results of this trial suggest that the improvement in feed efficiency due to steam process-flaking is more apparent than real. Considering the entire ration, including the basal which was fed at a maintenance level, steam process-flaking resulted in a 3.5 percent improvement in feed efficiency (statistically non-significant, ($P<.05$) compared to coarse grinding. When milo alone is considered, the difference in feed efficiency is very small. Perhaps any improvement in feed efficiency due to steam process-flaking results from a faster gain due to greater intake, with the feed required for maintenance therefore spread over a greater gain.

Even if this is true, however, it is obvious that advantages in intake, rate of gain, and apparent feed efficiency are important economically. Furthermore, the faster gaining steers on the steam process-flaked milo could be marketed earlier, and this might result in a real improvement in feed efficiency not demonstrated in this experiment in which steers were fed a constant time rather than to a constant weight.

Table 4. Slaughter and Carcass Information

	Method of Processing Milo				
	Coarsely Ground	Finely Ground	Reconstituted	Steam Process-Flaked	Reconstituted-Steam-Rolled
Dressing %[1]	60.8	61.2	61.4	61.7	60.6
Fat thickness, in.[2]	.50	.48	.58	.64	.52
Ribeye area, sq. in.[3]	10.5	11.0	10.7	11.3	10.7
Cutability, %					
Carcass basis[4]	51.0	51.5	50.8	50.6	51.1
Live basis[5]	31.0	31.5	31.2	31.2	31.0
Carcass grade[6]	9.6	8.2	9.4	9.7	9.3
Av. wt. of calculi, gm.[7]	2.4	2.6	2.5	10.8	3.7

[1] Calculated on basis of shrunk Ft. Reno live weight and chilled carcass weight.

[2] Average of three measurements determined on tracings of the ribeye.

[3] Determined by measurement of tracings of ribeye.

[4] Calculated as follows: percent of carcass as boneless trimmed retail cuts from the four major wholesale cuts = 51.34 (fat thickness) — .462 (percent kidney fat) + .740 (ribeye area) — .0093 (carcass weight).

[5] Trimmed retail cut yield as determined in footnote 4 multipled by dressing percent.

[6] USDA carcass grade converted to following numerical designations: high prime — 15, average prime — 14, low prime — 13, high choice — 12, average choice — 11, low choice — 10, high good — 9, average good — 8, low good — 7.

[7] Represents average total weight of calculi removed from bladder.

Reconstituting-rolling resulted in an improvement in feed efficiency, with no sacrifice in rate of gain, accompanied by a decreased grain intake, compared to coarse grinding. Steam processing of the reconstituted milo resulted in a further improvement in feed efficiency, with a further decline in feed intake but no decline in rate of gain. Even though these changes were not statistically significant, the possibility that further improvement in nutrient availability may be accomplished beyond the reconstitution process is recognized.

Fine grinding of milo resulted in good performance in this trial, as it has in previous experiments at this station. Feed efficiency was improved, and rate of gain did not decline. The decreased feed intake observed with this processing method, as with the reconstituted milos, was probably due to its greater utilization. Energy intake is one factor which governs feed intake; if utilization of a grain is increased, less is required to provide the same amount of energy. (The interesting observation in this regard is that steam process-flaking seems to improve palatability sufficiently to result in an increase in energy intake).

It should also be pointed out that the "coarse ground" milo used in this trial, ground through a hammer mill using a 3/16 inch screen, was considerably finer than that used in many feedlots which is undoubtedly utilized much more poorly than the "coarsely ground" milo used in this trial.

The results obtained in this experiment, as well as those reported from other stations, suggest interesting possibilities in milo processing. Many questions remain unanswered, and more information may be desirable before a change in processing method is made in many situations.

Equipment costs are an important consideration. The storage of high moisture grain in trench type facilities as well as air tight structures is a definite possibility.

Additional Information

Net energy values and volatile fatty acid production as affected by the processing methods used in this experiment will be reported later. The experiment itself is also being repeated. In addition, a trial is now in progress in which the following milo processing methods are being compared in a high concentrate (90 percent) ration: coarse grinding, fine grinding, dry rolling, steam process-flaking, reconstituting-rolling, and reconstituting-fine grinding.

Note: The particle size of milo, as influenced by the methods of processing, is illustrated in Figure 1, on page 101.

Influence of Level of Nitrogen Application to Wheat Pasture on Vitamin A Status of Beef Calves

Gale Thompson, S. A. Ewing and Robert Renbarger

Some producers have reported the occurrence of vitamin A deficiency symptoms among beef cattle grazing wheat pasture that had been fertilized with 50 or more pounds of actual nitrogen. The experiment reported is the first of a series of tests concerning level of nitrogen fertilization and the vitamin A status of calves grazing the forage.

Procedure

Twenty weaner heifer calves were selected from the Ft. Reno herd to serve as experimental animals. Five of the twenty heifers were selected at random for liver biopsy to obtain the initial levels of liver vitamin A and carotene prior to the grazing season. The remaining 15 calves were allotted to three groups and assigned to three wheat pasture fields which had been seeded with 16 lbs. of nitrogen per acre in a starter application. One field (control) received no additional nitrogen and the other two received applications of either 34 or 84 pounds of additional nitrogen after the wheat was up and prior to the beginning of the grazing season in November. As a result the three experimental pastures received 16, 50 and 100 lb. of actual nitrogen per acre prior to the grazing period. The stocking rate was approximately 1.1 acres per head. The grazing period consisted of 121 days from November 17, 1965 to March 18, 1966. The forage was sampled for nitrate analysis at the beginning and end of the grazing season and at one point (January) within the grazing period.

Blood samples were collected for plasma vitamin A and carotene analysis at the beginning and end of the grazing period as well as at an interim point (January) within the period. Liver samples were collected by biopsy technique from all calves at the end of the test to determine liver vitamin A and carotene levels.

Results

The results of this test are summarized in Table 1. It is readily apparent from the data that the vitamin A status of calves, reflected by either blood or liver levels of carotene and vitamin A, increased at approximately the same rate for all treatment groups. The nitrate content of the wheat forage was directly related to the level of nitrogen application. The highest concentration of nitrate was observed in the sample collected in January from the plot which had received the 100 pound nitrogen application. This level, however, is below what is normally considered a toxic level and apparently had no important influence on the status of vitamin A nutrition of the calves consuming the pasture.

Table 1. Influence of Nitrogen Fertilization of Wheat Pasture on the Vitamin A Status of Beef Calves.

LOT NO.	1	2	3
Total nitrogen applied/acre, lbs.	16	50	100
WEIGHTS:			
Initial wt. (11/17/65) lbs.	434	434	434
Final wt. (3/14/66) lbs.	588	557	562
PLASMA CAROTENE:			
Mcg./100 ml. (11/17/65)	354	488	343
Mcg./100 ml. (3/18/66)	1648	1880	1612
Difference	+1294	+1392	+1269
PLASMA VITAMIN A:			
Mcg./100 ml. (11/17/65)	25.88	30.20	29.16
Mcg./100 ml. (3/18/66)	56.10	61.60	53.30
Difference	+30.22	+31.40	+24.14
LIVER CAROTENE:			
Mcg./gram (11/3/65)	*5.2	*5.2	*5.2
Mcg./gram (3/18/66	14.7	19.4	16.2
Difference	+ 9.5	+14.2	+11.2
LIVER VITAMIN A:			
Mcg./gram (11/3/65)	*68.6	*68.6	*68.6
Mcg./gram (3/18/66)	153.3	161.1	156.7
Difference	+84.7	+92.5	+88.1
FORAGE NITRATE:			
PPM—Dry Matter (11/17/65)	35	140	245
PPM—Dry Matter (1/1/66)	210	245	1485
PPM—Dry Matter (3/22/66)	280	280	560

*Based on values observed for random sample biopsied at the beginning of the test period.

Urea Utilization By Ruminant Animals

By Allan D. Tillman

The usage of urea in ruminant rations is increasing at an ever-increasing rate until it appears likely that over 200,000 tons of the feed-grade product will be used for this purpose by 1970. If this projection is real, urea will account for about 20 percent of the high-protein feeds being used at that time and will replace 667,000 tons of soybean or cottonseed meal. The purposes of this paper are to consider some of the factors affecting urea utilization by ruminants.

The Ruminant Animal

The ruminant animal is able to utilize urea and other non-protein nitrogen sources because of the anatomy of his stomach. The true stomach (Figure 1) is preceded by three compartments, the rumen, reticulum and omasum. The reticulo-ruminal area is large and is often called a "fermentation vat." Herein live billions of bacteria and protozoa, which are capable of converting cellulose to soluble products which can be utilized by the host, synthesizing of certain vitamins, and converting non-protein nitrogen compounds to protein.

Fortunately for the ruminant animal, the reticulo-ruminal compartment is located at the head of the digestive tract, giving the bacteria and protozoa prior access to dietary nutrients, thus any products which are

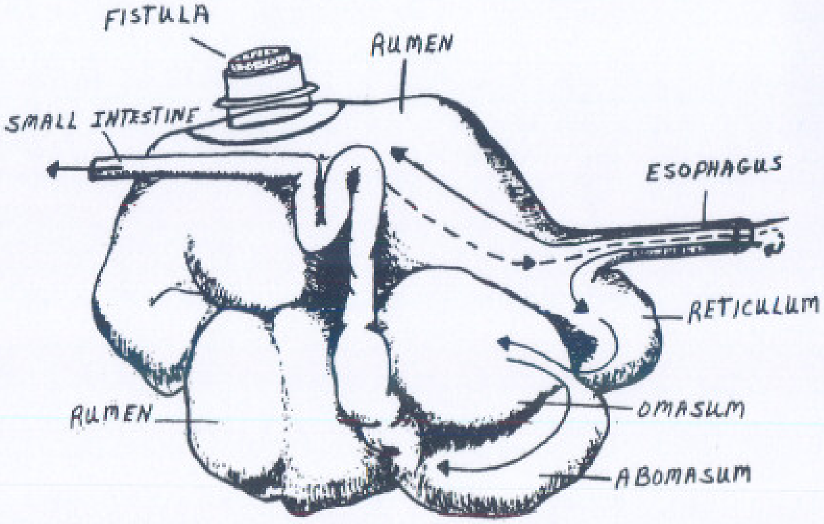

Figure 1. Schematic representation of the organs that comprise the stomach of the ruminant.

synthesized or partly catabolized here can be more completely absorbed than in non-ruminants which have their "fermentation vat" hooked onto the other end of their digestive tract.

How Ruminants Use Urea

All animals must have protein for maintenance, production and growth. Nathan Zuntz[1] in 1891 suggested that the micro-organisms in the rumen were important to the ruminant animal in its utilization of cellulose and nitrogen. Armsby[2] in 1911 reviewed the experimental evidence which concerned the utilization of urea and other non-protein compounds by ruminants and concluded that not enough of the non-protein compounds were converted to protein to be of significance in ruminant nutrition.

Research work on ruminant utilization of urea and other non-protein nitrogen compounds continued in Germany over the following 25 years

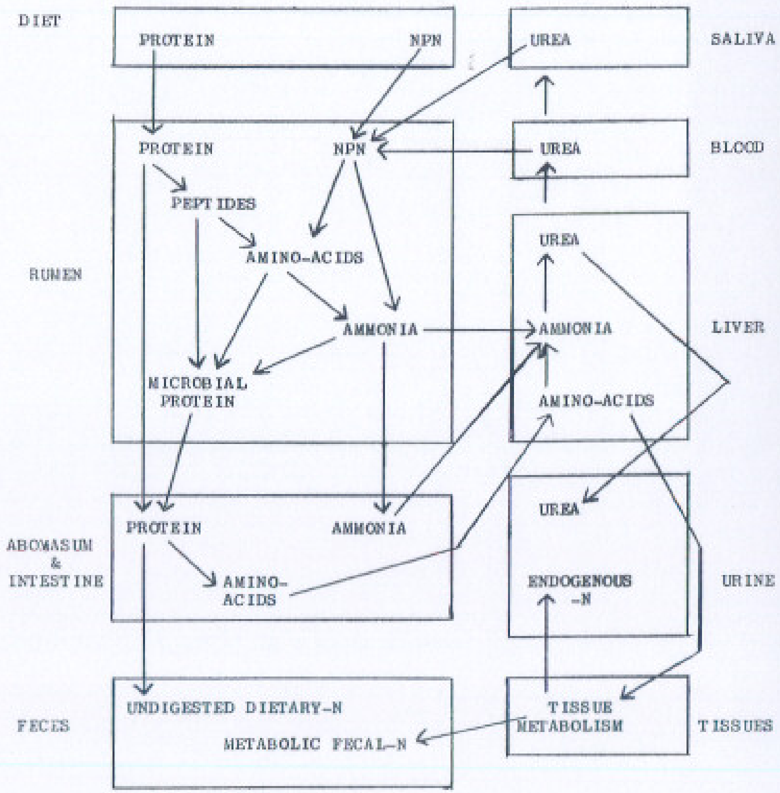

Figure 2. Nitrogen metabolism in the ruminant (Annison and Lewis[34])

and the review of Krebs[3] in 1937 was more optimistic than Armsby regarding the possibilities of using some urea in ruminant rations. Soon after Krebs' reviw several American laboratories began work on this problem. Wisconsin workers[4] found that when urea or ammonium bicarbonate was added to low-protein basal diets for calves that growth in these animals took place. Further research by the same group [5,6] was confirmatory as were results from Illinois [7,8,9], Massachusetts[10,11] and Cornell[12]. A review of the many feeding metabolism and toxicity reports, reveals the following findings:[13]

1. A low level of true protein and a high level of starch favors urea utilization[6].
2. Monosaccharides and disaccharides are inferior to starch for urea utilization[13].
3. Cellulose is hydrolyzed too slowly for effective urea utilization[13].
4. Highly soluble and easily hydrolyzable protein in the diet depresses urea utilization[13].
5. High levels of dietary protein reduce urea utilization. The more soluble proteins cause the greatest depression[6].
6. A deficiency of any minerals which are essential for rumen microorganisms, depresses urea utilization[14].
7. Urea should not replace over one-third of the natural protein in practical ruminant rations if optimum performance is to be obtained[13].
8. Frequent feedings stimulate urea utilization[15].
9. Under certain feeding conditions urea causes acute toxicity in ruminants[15].

Mechanism of Urea Utilization

As indicated earlier, the usage of urea in ruminant rations is increasing each year, yet basic microbiological changes involved in urea catalysis and subsequent synthesis of protein are obscure and but dimly perceived at the present time. Nontheless, the generally accepted sequence of events are as follows: (a) Microorganism urease in the rumen hydrolyzes urea to ammonia and carbon dioxide. (b) The ammonia nitrogen is combined with alpha-keto acids to synthesize amino acids, (c) amino acids are converted to microorganism protein, and (d) the microorganism protein is then digested to amino acids further down in the digestive tract and these are absorbed into the blood stream.

There is evidence[16] that the rate of urea hydrolysis (step a) exceeds synthesis of amino acids (step b) by a factor of about four. Under most conditions, there is enough buffering action in rumen fluid to convert the ammonia nitrogen to the ammonium ion. Ammonia has a pKa of 8.8 at 40°C[17] and the absorption across the rumen wall is slow if the pH is acid. As the pH of rumen fluid becomes alkaline more of the ammonium is converted to ammonia. The ammonia can penetrate the lipid layer of the ruminal wall in contrast to the impermeability of the charged ammonium ion. If excess urea is consumed, ammonia toxicity can result[15]. Levels of urea causing toxicity in fasted animals appear to be in the order of 20 grams per 100 pounds of liveweight but this can be modified by many factors which will be discussed later.

The basic problems of urea utilization may be presented if quantitative nutrient relationships are established. Feedgrade urea may contain 42 percent nitrogen*. Using the protein factor of 6.25, it can be seen that 100 grams of urea contains 42 grams of nitrogen and can supply 262 grams of protein if all of the nitrogen is converted to protein. Nitrogen makes 16 percent of the protein moiety, while carbon, hydrogen, oxygen and sulfur make up the remainder. If we consider the C, H and O to be in the same ratio as in carbohydrates, the main source of alpha keto acids, there would be 220 grams of this nutrient. This would mean that 2.2 gm. of carbohydrate must be added for each part of urea in the ration. As all dietary carbohydrates are not available for protein synthesis, there must be a much wider ratio than this. In purified diets, Oklahoma Workers [18,19,20] have used a ratio of 14 parts of starch plus dextrose to one part of urea and in the same ration of seven parts of cellulose to one part of urea. As cellulose is hydrolyzed too slowly to be of much value in supplying carbon fragments for animo acid synthesis[13], urea has not found wide usage in high roughage rations. The author and his graduate students have studies underway to determine the correct NFE: urea ratio when urea is fed in supplement for poor-quality roughage found in Oklahoma during the winter season.

Using Urea

The Association of America Feed Control Officials along with the American Feed Manufacturers Association have agreed on the following guide for the registration and subsequent labeling of urea-containing feeds found in the industry:

"Urea and ammonium salts of carbonic and phosphoric acids are acceptable ingredients in proprietary cattle, sheep and goat feeds only; these materials should be considered adulterants in proprietary feeds for other animals and birds; the maximum percentage of equivalent protein from nonprotein nitrogen must appear in the ingredient list.

"If feed contains more than 3 percent urea, or if the equivalent protein contributed by urea exceeds one-third of the total crude protein, the label shall bear: (1) a statement of proper usage; and (2) the following statement in type of such conspicuousness as to render it likely to be read and understood by ordinary individuals under customary conditions of purchase and use—WARNING: This feed should be used only in accordance with directions furnished on the label."

Feeders should follow very carefully these instructions. Failure to do so may result in loss of valuable cattle or sheep.

As Urea supplies only dietary nitrogen, which can be converted to microorganism protein if all other dietary factors are present in the

*Many feedgrade urea sources contain 45 percent N, but the principle of calculation is the same.

right quantities, it becomes of interest to compare ration conditions in which no urea utilization was obtained to those in which it was utilized. Such comparisons resulted in the recommendations already given. When urea is improperly used, toxicity may result. As Oklahoma[15], Florida[21], and English workers[22] have shown that 20 grams of urea/100 lb. body weight is toxic to cattle or sheep when consumed quickly or placed directly in the rumen, it is of interest to study conditions when the daily consumption of urea exceeds the above figure. Oklahoma workers[18,19,20] as well as Finnish workers[23] have fed purified diets to sheep and cattle. Urea supplied all of the dietary nitrogen in diets similar to that shown in Table 1. Sheep on this diet have gained at a rate up to 0.35[26] per day and while milk yields up to 9000 pounds per year have been obtained on several cows. Sheep, weighing 60 pounds, have consumed over five pounds per day of this ration, an intake of about 95 gm. of urea per day with no toxicity symptoms being observed. These animals consume their diets slowly and extend their feeding period over a large part of the day. Also, Oltjen (personal communication) of the United States Department of Agriculture, Beltsville, Maryland, using a diet similar to that shown in Table 1, has obtained normal reproduction in several cows. Such results indicate that urea may be used at higher levels than is recommended at this time. However, urea-containing rations require an adjustment period [24] before the ruminant can utilize it at the highest level of efficiency. There is no adequate explanation regarding the reason why such an adaptation period is necessary.

Beef Cattle Fattening Rations

Most beef cattle fattening-type rations in the United States now contain urea. Urea is usually incorporated into some premix, which contains a high level of protein, minerals, vitamins and other ration factors considered essential by the feeder. This is then mixed with other feeds

Table 1. Composition of the Oklahoma State University Purified Diet

Ingredient	Percent Level
Starch	29.38
Dextrose	29.38
Celulose (woodpulp)	30.00
Urea (46% N)	4.20
Corn oil	1.00
Polyethylene resin	1.00
Choline chloride	0.10
Minerals[1]	4.92
Vitamin A & D	0.02

[1] Each 100 lb. of diet contains the following mineral salts, in grams: Na_2B_407, 5.700; $CaHPO_4$, 0.893; $FeSO_4$, 19.300; KI, 0.031; K_2CO_3, 1005.400; $MnSO_4.H_2O$, 6.978; $Na_2MoO_4.2H_2O$, 0.227; $MgSO_4$, 54.500; $MgCO_3.Mg(OH)_2.3H_2O$, 121.000; Na_2SO_4, 113,400; Na_2SeO_4, 0.011; and $ZnSO_4.7H_2O$, 11.963. 601.000; CaF_2, 0.091; $CoCl_2.6H_2O$, 0.020; $Cr_2(SO_4)3$, 0.0181; NaCl, 283.500; $CuCo_3.Cu(OH)_2$,

in mobile mixing units while enroute to the animals. Examples of such premixes are the "Purdue 64"[25] and the "Iowa 80"[26] mixtures, composition of which are shown in Table 2. Such mixtures are usually fed at levels of one-half to one lb. per day per steer and urea consumption for each animal is from about 0.15 to 0.20 lb. per day, equivalent to 0.40 to .50 lb. of crude protein equivalent.

Urea has also found use in all concentrate rations for beef cattle. North Carolina Workers[27] have fed the diet shown in Table 3 and have results comparable to those when the oil meals are fed. (Also see McCartor and Tillman, p. 97)

The results attest that urea is an excellent substitute for the vegetable protein supplements in all ruminant rations containing high levels of grain.

High Roughage Ration

Still unanswered, however, are many problems regarding the use of urea in rations for mature cows being kept on low-protein forages during the winter season. The major deficiencies in such forages are minerals, especially phosphorus and certain trace elements, protein and energy. For many years the vegetable protein supplements have been used, and quite successfully so, to supplement such forages. As the world-wide shortage of protein has increased the demand for the oil meals in human nutrition, they are becoming expensive to feed to ruminants. Economics, therefore, dictate a wider usage of urea in such rations. Unfortunately, researchers have not been as successful in developing urea-containing supplements for ruminants kept under range conditions as in the case of fattening-type rations.

Nelson and Waller[28] summarized the results of 16 tests involving 879 cattle in which urea furnished one-third to one-half of nitrogen in supplements, which were isonitrogenous with cottonseed meal; cotton-

Table 2. Percentage Composition of Example Premixes for Beef Cattle Feeding. (Beeson et al.,[25] and Burroughs et al.,[26])

Rations	Purdue 64	Iowa 80
Dried molasses	---	33.0
Cane mola ses	14.0	---
Alfalfa meal	51.0	---
Bone meal	10.4	---
Iodized salt	3.5	---
$CaHPO_4$	---	20.0
$CaCO_3$	---	12.0
Trace minerals	---	1.0
Stilbestrol premix	---	2.0
Vitamin A mix	---	2.0
Urea	21.1	30.0
Total	100.0	100.0

Table 3. Percentage Composition of an All-Concentrate Diet for Beef Cattle (Wise et al[27])

Ingredient		Percent
Ground shelled corn		95.1
Urea		1.0
Cottonseed oil		2.0
NaCl		0.5
$CaCO_3$		0.7
Defluorinated phosphate		0.2
Trace minerals		0.4
Vitamin A & D		0.1
	Total	100.0

seed meal was replaced by urea and ground grain sorghum at about the ratio of one unit of urea plus six units of ground milo being equivalent to seven units of cottonseed meal. The urea-containing diets were greatly improved by the addition of trace minerals; however, animal performance was never as good as that in animals fed cottonseed meal. These results, along with the earlier results of Briggs *et al.*[20], indicate that the urea to NFE ratio in rations containing 40-45 percent crude protein is too narrow for good urea utilization and that supplements containing lower levels of crude protein and more starch or sugars are indicated. In this connection Beeson and Perry[30] modified the original Purdue Supplement A to include urea and the composition of these diets are shown in Table 4. When fed in diets containing corn cobs as the roughage, the urea-containing diet gave results as good as soybean meal. When corn cobs were the roughage source, daily gains of 1.28, 1.25, 1.14 and 1.17 lb., respectively, were obtained on rations 1, 2, 3 and 4. These differences were not significant. However more feed was required in the meal containing diets. Other workers[31] have obtained similar results when either corn cobs or corn stalks was the roughage source.

Table 4. Composition of Some Urea-Containing Supplements Fed with Poor Quality Forages (Beeson and Perry,[30])

Rations	1[1]	2[2]	3[3]	4[4]
Ingredients		Pounds per Days		
Soybean meal	2.25	1.06	0.46	---
Molasses feed (45% mol)[6]	1.00	2.85	3.75	4.46
Bone meal	0.18	0.18	0.18	0.18
Salt	0.06	0.06	0.06	0.06
Vitamin A & D	0.01	0.01	0.01	0.01
Urea	---	0.14	0.21	0.26
Total	3.50	4.30	4.67	4.97

[1] Original Purdue Supplement A.
[2] One-third of nitrogen from urea.
[3] One-half of nitrogen from urea.
[4] Two-thirds of nitrogen from urea.
[5] The percentages of urea in rations 2, 3 and 4, respectively, were 3.3, 4.5, and 5.2.
[6] 45 percent molasses dried on oat hulls and screenings.

Berry, *et al.*[32] fed cattle a diet composed of urea, molasses, phosphoric acid, trace minerals and vitamins and poor quality roughage free choice. The level of phosphoric acid can be varied in such mixtures to control intake when the liquid is fed free choice. Many of the commercial mixtures now available contain four percent phosphoric acid and these appear to be effective in limiting appetite of cattle on the dry ranges. As phosphoric acid is corrosive to metals and more diffecult to handle than other sources of phosphorus, there is interest in mechanical control of intake of urea-molasses mixture. The effectiveness of those devices available in commerce is not known by the author. The use of these supplements, of course, depends upon the price of molasses. When the price of molasses is that of milo or corn, these supplements become too expensive.

Toxicity

The major difficulty concerning the use of urea-containing protein supplements when poor-quality roughages are fed concerns the rapid hydrolysis of urea and the danger of toxicity if an animal consumes too much of the feed within a short time. Oklahoma workers[15] have studied in some detail toxicity symptoms when animals consume too much urea and these were as follows:

1. From 30 to 60 minutes after ingesting of urea, their steers showed uneasiness, staggering and kicking at the flanks.
2. These symptoms were followed by more serious incoordination, tetany and finally prostration.
3. These animals were down within 30 to 60 minutes after dosing. While prostrate, the most pronounced symptoms of distress were severe convulsions, slobbering at the mouth and bloating.
4. Ammonia levels of rumen contents were high which were quickly followed by high ammonia levels in peripheral blood.
5. There was a definite odor of ammonia on the breath of the animals.
6. Blood urea levels were high but cannot be taken as an indicator of severity of toxicity. When tetany begins, blood urea levels begin to drop.
7. Bloating was always present and the rumen contents had pH readings consistently above 8.0.
8. The amount of urea necessary to produce toxicity was about 20 grams per 100 lb. body weight.
9. All animals were dead within one to three hours after dosing.

Oklahoma workers[33] conducted further research on unusual feeding conditions which might cause urea toxicity and their results indicate that there are predisposing factors which increase the susceptibility of cattle and sheep to urea toxicity. These are as follows:

1. Animals which have never consumed urea appear to be the most susceptible.
2. Animals which have previously been consuming only low-

nitrogen roughages and are in a semi-starved condition will consume urea-containing feed rapidly.

3. Individual animals within the herd which are aggressive and consume their feed rapidly are most susceptible. In many cases where urea toxicity in the field has occurred, the rancher reports that his best animals were the victims.
4. Animals which have had previous access to urea-containing feeds will consume the diet slowly and will not consume enough urea to cause toxicity. In Oklahoma studies, sheep weighing 75 lb. have consumed over 80 grams of urea per day but consumption was slow; the animals simply nibble the feed and spend much more time at the feed trough. Also cattle weighing 500 lb. consumed in a similar manner over 400 grams of urea with no toxicity symptoms becoming apparent.

Prospects for Further Urea Usage

The results obtained by the Oklahoma and Finnish workers, in which ruminants were able to consume purified diets, containing urea as the sole nitrogen source, at levels necessary to maintain their body integrity, and then to put the surplus protein into body tissues and/or milk have opened up many possibilities of practical importance: Such tests must now be expanded to find other carbohydrate sources. For example, many countries have plenty of forests, thus the possibilities that certain wood products such as cellulose and hemi-cellulose, extracted in liquid form by the use of steam under pressure, might be combined with urea, minerals and vitamins to produce meat and milk products for feeding a protein-hungry world must be explored.

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The Performance of Beef Steers Fed Iso-Nitrogenous, Iso-Mineral All-Concentrate Rations

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The grain sorghums are deficient in several minerals as well as protein. The protein deficiency can be corrected by the addition of an oil seed meal and/or urea while mineral deficiencies are often corrected by the addition of a high quality roughage, such as alfalfa hay or dehydrated alfalfa meal, to the ration.

It would appear from a consideration of the chemical analyses that high- or all-concentrate rations based on milo and supplemented with cottonseed meal and dehydrated alfalfa would supply most minerals needed by fattening steers. However, if no cottonseed meal or alfalfa meal were included in the ration, it could be deficient not only in several major mineral elements, but also in several trace minerals.

The purpose of this trial was to determine whether the nutrients supplied by cottonseed meal and dehydrated alfalfa would improve the performance of fattening steers.

Experimental Procedure

The experiment was conducted in the beef cattle feeding facilities at the Panhandle A&M College, Goodwell, Oklahoma. One hundred and ten choice Hereford steers with an average initial weight of 720 lb. were randomly divided into five treatment groups. Rations 1, 2, 3 and 4 were each fed to 23 animals while ration 5 was fed to 18 animals. The groups were further subdivided into three subgroups and group-fed their respective diets for 143 days. All animals were hand-fed twice daily with feed records being kept on each subgroup. Water was available at all times.

The animals were weighed intially and at 28-day intervals during the trial. Compositions of the diets are shown in Table 1. Samples of milo were analyzed for nitrogen by the Kjeldahl procedure and for minerals by atomic absorption spectrophotometry. Chemical analysis of the dehydrated alfalfa meal and cottonseed meal were supplied by the American Dehydrators Association and the National Cottonseed Products Association, respectively. A separate premix was formulated for each treatment group in accord with ingredient analyses in an attempt to make the diets contain the same levels of crude protein and all minerals. Vitamin A, chlortetracycline and diethylstilbestrol were also added to the premix (see footnote 2, Table 1).

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Table 1. Percentage Composition of the Diets

Ingredients	Diets 1	2	3	4	5
Ground milo	87.50	84.75	96.25	91.50	87.75
Dehydrated alfalfa	-- --	5.00	-- --	5.00	5.00
Cottonseed meal[1]	8.10	7.00	-- --	-- --	3.20
Urea[1]	-- --	-- --	0.98	0.84	0.46
Premix[2,3]	4.40	3.25	2.77	2.66	3.59
Total	100.00	100.00	100.00	100.00	100.00

[1] All diets contained 12% crude protein.

[2] The amount of premix varied with each treatment to give the following levels of minerals in each diet: calcium, 0.35%; phosphorus, 0.30%; magnesium, 0.20%; sulfur, 0.13%; potassium, 0.70%; sodium, 0.20%; copper, 10 ppm; manganese, 30 ppm; iron, 80 ppm; cobalt, 0.1 ppm; iodine, 0.1 ppm; and zinc, 80 ppm.

[3] One pound of each ration contained 1500 I.U. vitamin A, 3.5 mg. chlorotetracycline and 0.5 mg. diethylstilbestrol; the concentration of each of these ingredients differed in each premix.

Table 2 shows the percentage of the total crude protein contributed by each ingredient. Feed grade urea containing 45 percent nitrogen was used in the appropriate diets. Technical grade minerals were used and the purity recorded by the suppliers were used in all calculations. The milo was dry-rolled before being mixed with the other ingredients. All diets were mixed in 2,000 lb. batches using a horizontal, double ribbon mixer.

Results and Discussion

Table 3 exhibits the feedlot performance data of the cattle. Feed consumption, gains, and feed efficiency were similar on all rations and were not different statistically. However, in agreement with results of other workers, cattle receiving cottonseed meal tended to eat more feed, gain faster, and make more efficient gains than those containing urea. The addition of dehydrated alfalfa meal did not improve the cottonseed meal- or urea-containing rations. As cottonseed meal is a rich

Table 2. Percentage of the Total Crude Protein Supplied by Each Ingredient

Ingredients	Diets 1	2	3	4	5
Ground milo	66.8	64.2	72.4	69.4	66.6
Cottonseed meal	33.2	28.7	----	----	13.2
Urea	----	----	27.6	23.5	13.1
Dehydrated alfalfa	----	7.1	----	7.1	7.1
Total	100.0	100.0	100.0	100.0	100.0

Table 3. Feedlot Performance of Steers (143-Day Test)

	Diets				
Item	1 CSM[1]	2 CSM+D[2]	3 Urea(u)[3]	4 U+D	5 CSM+U+D
Animals, Nos.	23	21[4]	23	22[4]	18
Final weight, lb.	1070	1050	1055	1066	1056
Initial weight, lb.	716	714	714	722	721
Daily gain, lb.	2.48	2.35	2.38	2.40	2.34
Daily feed, lb.	19.99	19.72	19.77	19.83	19.53
Feed/lb. gain, lb.	8.06	8.39	8.31	8.23	8.35

[1] CSM = Cottonseed meal
[2] D = Dehydrated alfalfa.
[3] U = Urea.
[4] Two animals were removed from diet 2 and one from diet 4 because of urinary calculi.

source of phosphorus and essential trace minerals, it was expected that the replacement of it by dehydrated alfalfa meal, which is also an excellent source of certain minerals, could dilute the diet as regards energy and result in slower gains. The results tend to support the idea, but it must be emphasized that the differences were not significant, statistically.

Since urea contains no essential minerals, one would expect that the addition of dehydrated alfalfa meal could improve animal performance; however, there was no improvement. As many workers have reported that the addition of dehydrated alfalfa meal improved cattle performance when highly-concentrated rations were fed, the results of the present trial indicate that their rations were deficient in one or more essential minerals and that these were corrected by the addition of dehydrated alfalfa meal. It thus appears that when all minerals are present in sufficient levels, no beneficial effects from the addition of dehydrated alfalfa meal are obtained.

Table 4 exhibits a financial statement on the trial. Feed costs are based upon feed prices at the time the trial was initiated. As the price of cottonseed meal was out of line in comparison to the price of urea, milo and mineral supplements to make these combinations equal in nitrogen and certain minerals, the urea-containing diet was more profitable than the one containing cottonseed meal. It thus appears that urea can serve as the sole source of supplemental nitrogen in all-concentrate diets containing milo if adequate minerals and vitamins are added and that such a substitution is desirable as regards profitable feeding of cattle.

Summary and Conclusions

One hundred and ten Hereford steers were used to compare urea and cottonseed meal as supplemental nitrogen sources in all-concentrate diets containing milo. In addition, dehydrated alfalfa meal was added to both the urea- and cottonseed meal- containing diets. A fifth ration contained urea, cottonseed meal, and dehydrated alfalfa meal. All rations contained the same levels of nitrogen and essential minerals.

Table 4. Financial Statement

Item	Rations 1 CSM[1]	2 CSM+D[2]	3 Urea(u)[3]	4 U+D	5 CSM+U+D
Final value—dollars[4]	273.00	268.00	269.00	272.00	269.00
Initial value—dollars[4]	200.00	199.50	199.50	202.00	202.00
Increase—dollars	73.00	68.50	69.50	70.00	67.00
Feed cost—dollars[5]	66.92	60.06	55.99	55.02	55.50
Return over feed—dollars	6.08	8.44	13.51	14.98	11.60

[1] CSM = Cottonseed meal.
[2] D = Dehydrated alfalfa.
[3] U = Urea.
[4] Appraisal values by experienced appraisers used for initial and final values.
[5] Actual cost of the feeds and no processing or mixing charges were assessed to any treatment.

Differences in feed consumptions, daily gains and feed efficiencies were not significant, indicating that urea can serve as the sole supplemental nitrogen source in all-concentrate diets containing milo if the diet is properly supplemented with minerals and vitamins. Neither the cottonseed meal- nor the urea-containing diets improved by the addition of dehydrated alfalfa meal.

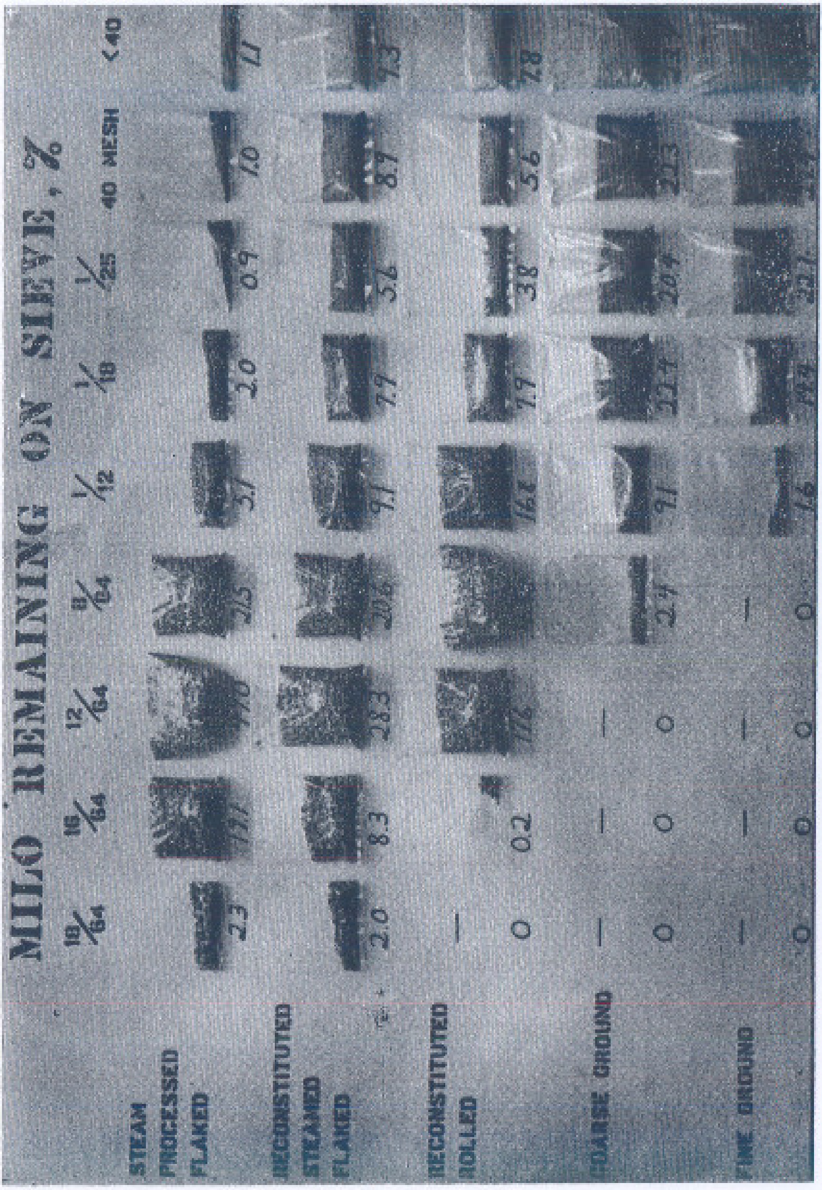

Figure 1. **Particle size of milo as affected by processing method. (See Methods of Processing Milo for Fattening Cattle, p. 70) The first seven columns show the percentage of milo remaining on each sieve of the indicated size (in inches). The eighth column shows the percentage of milo remaining on a 40-mesh sieve (about 1/100 inch), and the ninth column shows the percentage of milo passing through a 40-mesh sieve.**