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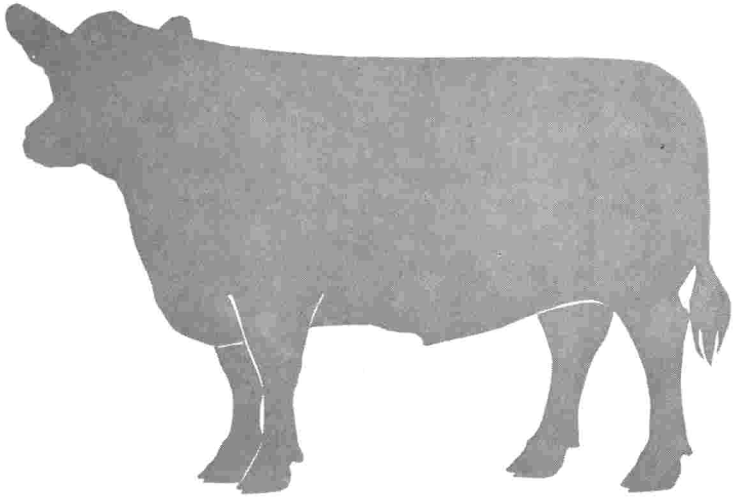

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by J. H. Clark O. G. Hall J. H. Felts

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SUMMARY

This study was conducted to compare the nutritional value of a complex protein supplement and cottonseed meal when fed with either orchardgrass or alfalfa hay. Artificial rumen studies and feeding trials were the techniques employed in this evaluation. The proximate composition of all feedstuffs was also determined. The results were as follows:

Artificial Rumen Results as a Prediction of Animal Performance.

1. In both 1963 and 1964 there were no significant differences between the complex protein supplement treatments and the cottonseed meal treatments in cellulose digestibility; however, digestibility values from the complex protein supplement treatments were slightly higher.
2. Average percent cellulose digestion in 1963 was significantly greater for alfalfa hay treatments than for orchardgrass hay treatments. In 1964, with better quality hays than in 1963, the reverse was true.
3. Artificial rumen results for 1963 showed in general which rations would produce the better gains in the feedlot; however, feedlot gains in 1964 did not follow the trends of the artificial rumen results.

Animal Performance.

1. With respect to average daily gains, feed required per hundredweight of gain, dressing percentages, or carcass weight, there were no significant differences between steers fed a complex protein supplement and those fed cottonseed meal in either trial.
2. Rations containing alfalfa hay produced significantly greater average daily gains, higher dressing percentages, and heavier carcasses in both trials than did rations containing orchardgrass hay.
3. For the 2 years, steers fed ground ear corn, alfalfa hay, and cottonseed meal made the cheapest gains (20.4¢/lb. gain) and steers fed ground ear corn, orchardgrass hay, and complex protein supplement made the highest priced gains (21.3¢/lb. gain). The average sale price per hundredweight for all steers in each treatment was $23.50.
4. The data indicate that the best animal performance was obtained with alfalfa hay, and that either of these protein supplements are acceptable for use in finishing steer rations. The choice depends primarily on the price per pound of crude protein equivalent in the supplement, provided good quality hay is being fed.

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CONTENTS

Performance of Beef Steers Fed Different Protein Supplements and Hays In the Feedlot

by

J. H. Clark, O. G. Hall, and J. H. Felts[1]

Feeding beef cattle for the slaughter market has developed into an important phase of the beef cattle industry in Tennessee and the Southeast generally. It is anticipated that this phase of the industry will increase in importance in the future. Protein level is important in fattening rations for beef cattle. Since protein supplements are the most expensive ingredients in such rations, beef cattle feeders are very interested in those which will supply satisfactory protein at the lowest possible cost.

Generally speaking, there are four types of protein supplements fed to beef cattle: 1) a single plant protein supplement, 2) a mixture of plant protein supplements, 3) a protein supplement fortified with vitamins and minerals, and 4) a high urea supplement which can be either fortified or unfortified. Cottonseed, soybean, and linseed meals are the most commonly used and readily available protein supplements for feeding cattle. However, Morrison (1956) states that complex supplements or mixtures containing supplemental nitrogen or protein, minerals, and certain other factors needed by rumen bacteria have improved digestion when fed with roughages of very low quality, such as corncobs, straw, or cottonseed hulls. Thus, the quality of the roughages with which protein supplements are to be fed, as well as the cost of the protein supplements, should be considered when deciding which protein supplement to use.

In the Southeast, cottonseed meal is used extensively in beef cattle rations because of its availability and cost. It is rich

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enough in protein (usually 41-44%) so that only small amounts are required to balance rations otherwise low in this nutrient. According to Morrison (1956) and Snapp and Newman (1960), cottonseed meal is one of the best protein supplements for beef cattle, dairy cows, and sheep. Adding cottonseed meal to shelled corn, corn silage, and oat straw has a markedly beneficial result on the gains and finish of cattle. Animals fed cottonseed meal consume larger quantities of both concentrates and roughages and are easier to keep on feed than those not receiving a protein supplement.

Most fortified mixed supplements are patterned after the well-known Purdue Supplement A which consists of a nitrogen or protein source, an energy source, vitamins, and minerals. This type of supplement is commonly fed at the rate of 1 to 3½ pounds per day depending upon the ration composition and the type of cattle to which it is fed. In reports from the Midwest this kind of fortified mixed protein supplement has been highly recommended when the ration contains low quality roughages. Ohio workers (Gerlaugh **et al.**, 1934) reported that steers fed a ration containing 1.6 pounds of an all-purpose supplement gained 50 pounds more per calf in 280 days with a better feed efficiency than calves fed 2 pounds of equal parts linseed meal and cottonseed meal. However, in two experiments, Anderson (1965) at Tennessee found that little difference in gain was observed between cottonseed meal and a fortified commercial protein supplement fed at the same crude protein level. Both the feed requirements and the final dollar value differences were small and offset each other to the extent that the return per head over feed cost was almost identical for both supplements.

Due to the variations that are often obtained in various sections of the country, a series of experiments was conducted at the Tobacco Experiment Station at Greeneville during 1963 and 1964 to determine the comparative effectiveness of supplementing finishing rations for steers with either cottonseed meal or a complex protein supplement. Alfalfa and orchardgrass hays in combination with one of the two protein supplements were also compared. The two methods of evaluating the rations used in this study were the "artificial rumen" and feedlot trials.

EXPERIMENTAL PROCEDURE

Feeds Used. The complex protein supplement used in these experiments was formulated and mixed at the University of Tennessee. Its composition, which is similar to some of the complex protein supplements fed in Cornbelt experiments, is shown in Table 1. It contained 44.02% crude protein which was slightly higher than the 43.64% crude protein in the cottonseed meal.

Table 1. Composition of the complex protein supplement[a]

Ingredient	Percent
Cottonseed meal	63.5
Dehydrated alfalfa meal (17%)	15.0
Molasses	10.0
Urea (262% crude protein equivalent)	5.0
Dicalcium phosphate	5.0
Trace-mineralized salt	1.5

[a]5000 I.U. Vitamin A added per lb.

Orchardgrass and alfalfa hays produced during 1963 and 1964 on the University of Tennessee Tobacco Experiment Station in Greene County in northeast Tennessee were used in these experiments. The orchardgrass hay was the first cutting and it had been fertilized with 300 pounds of 5-15-15 in March of each year. Second or third cutting Buffalo alfalfa hay was produced from a 2- or 3-year-old stand in 1963 and 1964, respectively. It had been fertilized with 500 pounds per acre of 0-9-27 in October of each previous year. All hays were produced under natural conditions. The digestion coefficients shown in Table 2 were obtained when the respective hays alone were fed to steers.

Table 2. Digestion coefficients of orchardgrass and alfalfa hays as determined in steer digestion trials (% dry matter basis)

	Orchardgrass		Alfalfa	
	1963	1964	1963	1964
Dry matter	54.7	69.3	63.4	63.2
Crude protein	54.5	67.1	72.9	75.2
Crude fiber	53.4	72.4	45.5	44.1
Ether extract	40.7	51.3	57.5	38.0
Nitrogen-free extract	56.3	70.0	73.8	73.6
Energy	51.5	66.1	62.1	61.1
TDN	52.1	65.9	60.4	58.4

Artificial Rumen Studies. In the experiments reported here, rumen microbial activity—as measured by cellulose digestion in the artificial rumen—was used to indicate how well the feeds would be utilized by steers in the feedlot. The content of the artificial rumen includes three ingredients: 1) the finely ground substrate or feeds, 2) a buffer solution, and 3) the washed rumen bacteria without rumen juices and residues, all of which were combined in a glass fermentation flask. The artificial rumen simulates the digestive conditions and processes in the rumen by which feeds are fermented and converted into digestible products by the enzymes of the rumen microorganisms. Among the many advantages of an artificial rumen are:

1) Little expense and labor are required in comparison to feedlot trials.
2) Data can be obtained rapidly.
3) Only small quantities of feed are necessary.
4) Large numbers of rations from the feedlot can be studied simultaneously, since each individual fermentation flask represents one animal in the feedlot.

A series of three separate experiments was conducted each year using bacteria obtained on different days. Each experiment consisted of four treatments: 1) orchardgrass hay plus cottonseed meal, 2) orchardgrass hay plus complex protein supplement, 3) alfalfa hay plus cottonseed meal, and 4) alfalfa hay plus complex protein supplement. The ratio of hay to protein supplement in all treatments was 2:1. This was the ratio in which these ingredients were to be fed in the feedlot along with a full feed of ground ear corn. Each treatment was duplicated within each experiment giving a total of six observations for each treatment.

The artificial rumen procedure used for this study was that of Cheng, Hall, and Burroughs (1955), with minor modifications. Rumen bacteria were obtained from a rumen-fistulated beef steer fed a mixture of good quality alfalfa and orchardgrass hays, a complex protein supplement, cracked corn, salt, and fresh water. Rumen contents were removed from the steer about 5 hours after the morning feeding.

Liquid containing billions of microorganisms was squeezed from the rumen contents and strained through cheesecloth into

a previously warmed thermos bottle. The strained rumen liquid was then taken to the laboratory and the bacteria were separated from the liquid in a high-speed centrifuge. Then the rumen bacteria were washed twice in a sodium bicarbonate buffer solution. Fifteen milliliter-portions of the buffered suspension containing the bacteria were added to 50-milliliter fermentation flasks which contained 0.45 gram of the ground ration suspended in 15 milliliters of the sodium bicarbonate buffer solution.

The flasks were placed in a water bath maintained at 39 degrees C. Carbon dioxide gas was bubbled through the contents of the flasks throughout the 24-hour fermentation period. Cellulose content of each treatment and cellulose which remained in the flasks at the end of the 24-hour fermentation period, were chemically determined using the procedure of Crampton and Maynard (1938). From these results, cellulose digestibility was calculated. Treatment differences between means were statistically analyzed using methods outlined by Snedecor (1956).

Feeding Trials. Fifty-six yearling Hereford steers grading Good-plus in type and averaging about 800 pounds in body weight were used each year (1963 and 1964). Each year the steers grazed good pastures for approximately 150 days before the experiment. In 1963, the steers were started on feed September 6 and fed for 88 days, while in 1964 they were started July 14 and fed for 99 days. The steers were divided into comparable lots of 7 steers per lot based on weight, type, and condition. Two lots of steers, selected at random, were then assigned to one of the four experimental rations. The following rations were fed daily:

1) Ground ear corn free choice, 4 pounds of orchardgrass hay, and 2 pounds of cottonseed meal.
2) Ground ear corn free choice, 4 pounds of orchardgrass hay, and 2 pounds of complex protein supplement.
3) Ground ear corn free choice, 4 pounds of alfalfa hay, and 2 pounds of cottonseed meal.
4) Ground ear corn free choice, 4 pounds of alfalfa hay, and 2 pounds of complex protein supplement.

Fresh water, salt, and dicalcium phosphate were provided free choice to all cattle. Samples of all feeds were taken throughout the feeding trials and chemically analyzed for dry matter,

crude protein, crude fiber, ether extract, ash, and nitrogen-free extract by A.O.A.C. (1960) methods. Gross energy was determined in a Parr Adiabatic Type Oxygen Bomb Calorimeter.

Averages of two weights taken on consecutive days were used as the beginning and final experimental weights. In addition the steers were weighed at 28-day intervals throughout the experimental period. All steers were graded by two qualified graders of the Animal Husbandry-Veterinary Science Department at the beginning and end of the experiment.

The steers were sold to a packing plant in Bristol in 1963 and in 1964 they were sold to a packing plant in Knoxville. All animals were weighed and tagged for identification as they were slaughtered. Individual warm carcass weights were taken immediately after the carcass was washed and carcass grades were obtained from the local USDA grader at the packing plant. The feed prices shown in Table 3 represent the approximate cost of each ingredient during the years 1963 and 1964. The data obtained in these experiments were analyzed statistically by analysis of variance techniques described by Snedecor (1956).

Table 3. Feed prices used to compute costs of gains

Ingredient	Price/Ton
Ground ear corn	$40.00
Cottonseed meal	80.00
Complex protein supplement	85.00
Orchardgrass hay	32.00
Alfalfa hay	38.00

RESULTS AND DISCUSSION

Nutrient Composition of Feeds. The chemical composition of the feeds is shown in Table 4. The crude protein content of the complex protein supplement was 44.02% and of the cottonseed meal, it was 43.64%. Dry matter, crude fiber, nitrogen-free extract, ether extract, and gross energy were slightly higher in the cottonseed meal, but ash was over twice as high in the complex protein supplement. Supplemental minerals account for the high ash content of the complex protein supplement.

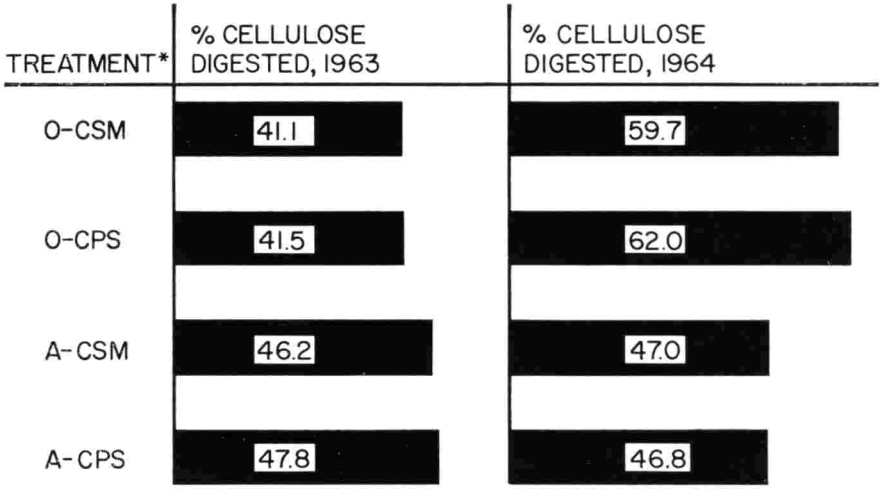
Table 4. Nutrient composition of feeds

Feed Constituent	Year	Dry matter	Crude protein*	Crude fiber*	N.F.E.*	Ether extract*	Ash*	Gross energy*
		%	%	%	%	%	%	Kcal./gm.
Cottonseed meal	1963-64	92.31	43.64	11.94	34.18	4.15	6.09	4.86
Complex protein supplement	1963-64	90.69	44.02	11.52	28.62	3.35	12.49	4.28
Alfalfa hay	1963	90.63	16.96	29.71	43.10	2.05	8.18	4.44
Orchardgrass hay	1963	91.63	8.74	33.80	48.17	2.44	6.84	4.42
Alfalfa hay	1964	90.99	20.62	30.38	38.22	1.64	9.14	4.35
Orchardgrass hay	1964	91.87	14.04	31.16	43.69	2.85	8.26	4.31

*Dry matter basis

The crude protein content of the hays varied considerably from year to year. In both hays the crude protein was higher in 1964 than in 1963, and in both years it was greater in the alfalfa hay than in the orchardgrass hay. All hays supplied approximately the same amount of dry matter. However, the orchardgrass hay in both years contained slightly more crude fiber than did the alfalfa hay. Both alfalfa and orchardgrass hays produced in 1964 were greener and more leafy than those produced in 1963.

Animal Performance as Predicted by the Artificial Rumen. Cellulose digestibility as determined in the artificial rumen in 1963 is summarized in Figure 1. There was essentially no dif-



*O-CSM=Orchardgrass hay-cottonseed meal
O-CPS=Orchardgrass hay-complex protein supplement
A-CSM=Alfalfa hay-cottonseed meal
A-CPS=Alfalfa hay-complex protein supplement

Figure 1. Percent cellulose digested by rumen microorganisms. (Each figure represents the average of six determinations.)

ference in cellulose digestibility due to protein supplements. However, cellulose digestion in alfalfa hay was significantly greater ($P<0.01$) than in the orchardgrass hay.

Artificial rumen data of the 1964 treatments are also shown in Figure 1. Again, there were no statistically significant dif-

Table 5. Effects of type of protein supplement and hay on feedlot performance of yearling beef steers

(Average results of two experiments—see Appendix Tables I and II)

	Orchardgrass Hay		Alfalfa Hay	
	Cottonseed meal	Complex protein supplement	Cottonseed meal	Complex protein supplement
No. of steers/lot	7	7	7	7
No. of steers/treatment	14	14	14	14
Av. wt. and gain/hecd, lb.				
Initial wt.	805	807	810	809
Final wt.	1017	1016	1040	1031
Total gain	212	210	230	222
Daily gain	2.27	2.25	2.46	2.39
Av. daily ration, lb.				
Ground ear corn	16.6	16.6	17.1	17.2
Protein supplement	2.0	2.0	2.0	2.0
Hay	4.0	4.0	4.0	4.0
Feed req./cwt. gain, lb.				
Ground ear corn	733	741	698	724
Protein supplement	87	88	81	83
Hay	174	176	160	166
Total	994	1005	939	973
Feed costs/lb. gain[1]	20.9¢	21.3¢	20.4¢	21.2¢
Grades[2]				
Initial type	10.4	10.3	10.2	10.4
Initial condition	7.9	7.9	7.9	7.9
Final condition	11.1	11.1	11.2	11.2
Federal carcass	10.4	10.7	10.8	10.8
Shrinkage	2.90	2.63	2.88	2.74
Av. carcass wt.[3]	583	586	610	606
Dressing percent	57.3	57.7	59.0	59.0
Av. sale price/cwt., $	23.50	23.50	23.50	23.50

[1]Table 3.

[2]11 = high Good.
7 = av. Standard

[3]Hot carcass wt.

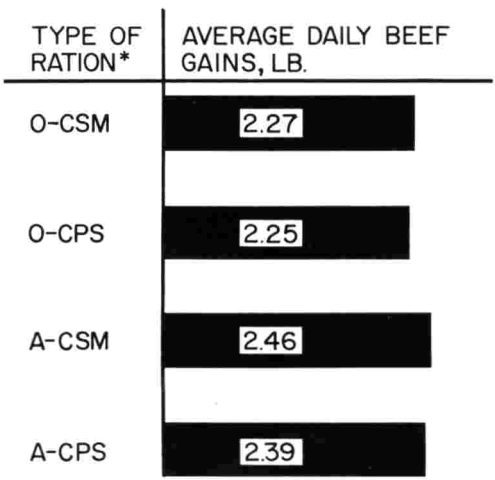
ferences between the two protein supplements. However, in contrast to data from 1963, cellulose digestibility in orchardgrass hay was significantly higher ($P<0.05$) than in alfalfa hay. Possible reasons for the low digestibility of cellulose in the 1963 orchardgrass hay were higher crude fiber, lower ash, and perhaps increased lignification of the forage. However, if the protein content of the whole ration was limiting, then the lower protein con-

tent in the orchardgrass hay could also have contributed to the lower digestibility.

Animal Performance as Determined in the Feedlot. Combined 2-year feedlot performance of beef steers fed the four experimental rations is summarized in Table 5. The results of the two experiments were also calculated individually and are given in Appendix Tables I and II.

In 1963, although there were no significant differences in average daily gain, the steers fed the complex protein supplement gained slightly faster than those fed the cottonseed meal. This slight increase in average daily gain could possibly have been due to the quality of hay used in 1963. When both years were considered, steers fed the cottonseed meal rations gained 0.05 pound per day faster than those fed the complex protein supplement rations. These differences were not statistically significant.

Although all gains were satisfactory, data in Table 5 and Figure 2 show that steers fed alfalfa hay gained significantly ($P<0.05$) faster than those being fed orchardgrass hay (2.42



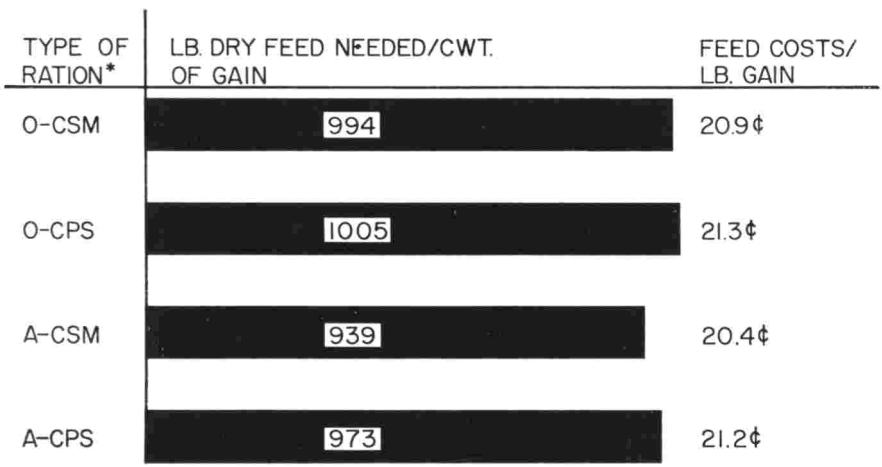
*O-CSM = Orchardgrass hay-cottonseed meal
O-CPS = Orchardgrass hay-complex protein supplement
A-CSM = Alfalfa hay-cottonseed meal
A-CPS = Alfalfa hay-complex protein supplement

Figure 2. Average daily gains of beef steers fed different protein supplements and hays (average of two experiments).

versus 2.26 lb./day, respectively). This was as expected since animals usually perform better on alfalfa hay than on other hays.

Table 5 and Figure 3 show the feed required per hundredweight of gain. There were no significant differences in the feed required per hundredweight of gain due to protein supplements. Although the feed required per hundredweight of gain was greater for the orchardgrass hay-fed steers than for the alfalfa hay-fed steers, the difference was not significant.

The feed cost per pound of gain was highest for the orchardgrass hay plus complex protein supplement (Table 5 and Figure 3), while the alfalfa hay plus cottonseed meal produced the



*O-CSM=Orchardgrass hay-cottonseed meal
O-CPS=Orchardgrass hay-complex protein supplement
A-CSM=Alfalfa hay-cottonseed meal
A-CPS=Alfalfa hay-complex protein supplement

Figure 3. Average amount of dry feed required per 100 pounds of gain and feed costs per pound of gain of beef steers fed different hays and protein supplements and hays.

cheapest feed costs per pound of gain. Even though the feed cost per pound of gain was highest for the orchardgrass hay plus complex protein supplement for the 2 years, in 1963 this type of ration produced the cheapest gains. However, in 1964 it produced the highest costs of gains of any of the treatments (Appendix

Tables I and II). This might be expected, since the hays were of poorer quality in 1963 than in 1964. Over-all results tend to indicate that the complex protein supplement caused a slight increase in the feed costs per pound of gain.

Table 5 also contains the carcass data obtained from the steers. The average dressing percentages of the cottonseed meal-fed steers did not differ significantly from those of steers fed the complex protein supplement. The alfalfa hay-fed steers had an average dressing percentage which was significantly higher ($P<0.01$) than that of steers receiving orchardgrass hay (59.0% versus 57.5%, respectively). Steers in 1964 had significantly ($P<0.01$) higher dressing percentages than those on respective treatments in 1963.

Carcass weights of steers fed the two protein supplements were not significantly different; however steers fed alfalfa hay had significantly ($P<0.05$) heavier carcasses than those fed orchardgrass hay. Steer carcasses in 1964 were significantly ($P<0.01$) heavier than in 1963. This was probably due to the higher dressing percentage as well as the heavier weights of the animals throughout the 1964 trial. It could be attributed also to the fact that the feeding period in 1964 was 11 days longer than in 1963.

Shrinkage was greater for steers fed cottonseed meal than for those fed the complex protein supplement, however, not significantly so. There was little difference between treatments with respect to initial type, initial condition, final condition, or federal carcass grade. The average sale price of all animals was $23.50 per hundred pounds.

General Comments. Based on the results of the trials reported in this bulletin, the feeding of a complex protein supplement will not result in any improvement over cottonseed meal with respect to average daily gain, feed efficiency, or dressing percentage, providing good quality hay is fed. Therefore, if a good quality roughage is being fed, the type of protein supplement to feed depends upon the cost per pound of actual crude protein equivalent in the supplement.

Results for the 1963 artificial rumen studies showed general

indications as to which rations would produce the best gains in the feedlot; however, feedlot data in 1964 did not follow the indications of the results in the artificial rumen. It should be pointed out that these results are for only 2 years' work conducted at one location.

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APPENDIX

Appendix Table I. Effects of type of protein supplement and hay on feedlot performance of yearling beef steers, 1963

	Orchardgrass Hay		Alfalfa Hay	
	Cottonseed meal	Complex protein supplement	Cottonseed meal	Complex protein supplement
No. of steers/lot	7	7	7	7
No. of steers/treatment	14	14	14	14
Av. wt. and gain/head, lb.				
Initial wt.	797	798	798	798
Final wt.	997	1007	1013	1021
Total gain	200	208	215	222
Daily gain	2.27	2.37	2.44	2.53
Av. daily ration, lb.				
Ground ear corn	16.3	16.2	17.4	17.6
Protein supplement	2.0	2.0	2.0	2.0
Hay	4.0	4.0	4.0	4.0
Feed req./cwt. gain, lb.				
Ground ear corn	716	686	714	695
Protein supplement	87	83	81	78
Hay	173	166	161	156
Total	976	935	956	929
Feed costs/lb. gain[1]	20.6¢	19.9¢	20.6¢	20.2¢
Grades[2]				
Initial type	10.4	10.4	10.1	10.5
Initial condition	7.8	7.7	7.7	7.8
Final condition	11.1	11.3	11.0	11.1
Federal carcass	10.2	10.6	10.9	10.9
Shrinkage	2.74	2.47	2.53	2.62
Av. carcass wt.[3]	564	568	591	597
Dressing percent	56.6	56.4	58.3	58.4
Av. sale price/cwt., $	23.85	23.85	23.85	23.85

[1]Table 3.

[2]11 = high Good
7 = av. Standard.

[3]Hot carcass wt.

Appendix Table II. Effects of type of protein supplement and hay on feedlot performance of yearling beef steers, 1964

	Orchardgrass Hay		Alfalfa Hay	
	Cottonseed meal	Complex protein supplement	Cottonseed meal	Complex protein supplement
No. of steers/lot	7	7	7	7
No. of steers/treatment	14	14	14	14
Av. wt. and gain/head, lb.				
Initial wt.	812	816	821	820
Final wt.	1036	1025	1066	1041
Total gain	224	211	245	222
Daily gain	2.26	2.13	2.47	2.24
Av. daily ration, lb.				
Ground ear corn	16.9	16.9	16.8	16.8
Protein supplement	2.0	2.0	2.0	2.0
Hay	4.0	4.0	4.0	4.0
Feed req./cwt. gain, lb.				
Ground ear corn	749	796	682	753
Protein supplement	87	93	80	88
Hay	174	185	159	176
Total	1010	1074	921	1017
Feed costs/lb. gain[1]	21.2¢	22.6¢	20.1¢	22.1¢
Grades[2]				
Initial type	10.3	10.2	10.2	10.3
Initial condition	7.9	8.0	8.0	7.9
Final condition	11.1	10.8	11.4	11.2
Federal carcass	10.5	10.7	10.7	10.7
Shrinkage	3.05	2.79	3.23	2.85
Av. carcass wt.[3]	601	603	628	615
Dressing percent	58.0	59.0	59.7	59.5
Av. sale price/cwt., $	23.15	23.15	23.15	23.15

[1]Table 3.

[2]11 = high Good
7 = av. Standard.

[3]Hot carcass wt.

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Main Station, J. N. Odom, General Superintendent of Farms, Knoxville
University of Tennessee-Atomic Energy Commission Agricultural Research Laboratory, Oak Ridge, N. S. Hall, Laboratory Director

Branch Stations

Dairy Experiment Station, Lewisburg, J. R. Owen, Superintendent
Highland Rim Experiment Station, Springfield, L. M. Safley, Superintendent
Middle Tennessee Experiment Station, Spring Hill, J. W. High, Jr., Superintendent
Plateau Experiment Station, Crossville, J. A. Odom, Superintendent
Tobacco Experiment Station, Greeneville, J. H. Felts, Superintendent
West Tennessee Experiment Station, Jackson, B. P. Hazlewood, Superintendent

Field Stations

Ames Plantation, Grand Junction, James M. Bryan, Manager
Cumberland Plateau Forestry Field Station, Wartburg, J. S. Kring, Manager
Friendship Forestry Field Station, Chattanooga
Highland Rim Forestry Field Station, Tullahoma, P. J. Huffman, Jr., Manager
Milan Field Station, Milan, T. C. McCutchen, Manager
Oak Ridge Forest and Arboretum, R. D. MacDonald, Manager

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