Efficiency of Converting Nutrients and Cultural Energy in Various Feeding and Grazing Systems

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Highlight: *Yearlong total confinement and partial confinement feeding were compared to conventional range grazing to determine the cultural and digestible energy expended to produce a kilocalorie of dressed-carcass meat from weaner calves and the protein consumed to produce a pound of red-meat protein. The range groups required the least amount of cultural energy to produce a kilocalorie of meat and the total confined groups required the most. The total confined system on a low level of nutrition, where calves were weaned early, converted digestible energy most efficiently but converted digestible protein least efficiently, whereas range groups converted digestible energy least efficiently and digestible protein most efficiently.*

During the past 30 years more intensive cropping systems have enabled agriculture to double crop production; however, use of fossil fuel has increased 2.3 times for each increment of food produced. During the past few years, grain has been a surplus commodity and, as a result, has been considered cheap livestock feed. Feeding high grain rations has increased the cultural energy used in the production of meat compared to the use of range forage which is produced primarily from solar energy. The world no longer has surplus food to feed an ever-increasing population, and the expenditure of the finite fossil fuels for food production therefore becomes a grave concern.

Cultural energy is the energy included in fossil fuels or other sources of energy that supplements solar energy in the production of food. This energy comes from labor, transportation, and electricity to produce and process foods. The energy required to manufacture machinery, fertilizers, and pesticides that are used in agriculture is also considered energy that subsidizes solar energy in producing plant growth.

As a result of the concern for the increasing expenditure of cultural energy for food production, a study of six feeding and grazing systems of beef cattle was analyzed to determine the cultural and digestible energy expended to produce a kilocalorie of table meat from weaner calves. The study was carried out at the Eastern Colorado Experiment Station from 1971 to 1974.

Procedures

In October 1971, 166 mature Hereford cows were divided into six groups to test three management systems at the Eastern Colorado Range Research Center. These systems were:

1. Native Range: 15 acres of rangeland per animal unit for 12 months.
   a. Thirty cows were rotated on three 150-acre pastures at 2-month intervals and supplemented with 1 lb alfalfa pellets per head per day from November 1 to May 1.
   b. Same as above with cows receiving a winter supplement of 2 lb alfalfa pellets per day.
2. Semiconfinement: 10 acres of rangeland per animal unit for 7 months.
   a. Thirty cows were rotated on three 100-acre pastures from May 1 to December 1 and fed in drylot from December 1 to May 1 with the nutrient intake regulated at 6½ lb TDN (total digestible nutrients per day.
   b. Same as above with the drylot nutrient intake regulated at 8½ lb TDN per day.
3. Total Confinement: drylot 12 months.
   a. Twenty-three cows were maintained on 6½ lb TDN per day except for the period April 15 to July 15, when they received 14 lb TDN. Calves had access to creep feed until weaned at 90 days of age, after which they were bunk fed a growing ration until October 14.
   b. Twenty-three cows were maintained on 8½ lb TDN per day from October 15 to April 15 and 14 lb TDN from April 16 to October 14. Calves were creep fed and weaned October 15.

Cows confined to the drylot were fed sorghum silage, alfalfa hay, grain, salt, and mineral. The calves of the cows receiving 8½ lb TDN per day were creep fed a grain mixture for approximately 60 days following birth and were then fed silage, hay, and grain with enough soybean oil meal added to maintain the crude protein level above 15%.

Cows in confinement were bred artificially during a 40-day period and those in partial confinement and on native range were artificially inseminated during a 30-day period. Bulls were put with all cows for an additional 20 to 30 days and left long enough to make a 60-day breeding season.

Calculating Cultural Energy in Feeds Used

All cultural energy charged to feeds used in the trials was calculated after the outline used by Pimental et al. (1973) and Heichel (1973). The individual crops used as feed and the input of cultural energy is shown in Tables 1 and 2.

It has been estimated that most agriculture machinery has about 8,000 kcal of cultural energy invested per pound and can be depreciated over an average life of 5 to 8 years (Slesser, 1973). It was calculated that a 7-ton tractor depreciates over a 6½-year period to the extent of about 17,300 megacalories per year. Farm pickups and trucks have been said to contain

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Table 1. Average cultural energy (Mcal) inputs per acre for the production of the feeds used in the trials presented herein.

Type of input	Alfalfa[2] Units of input	Alfalfa[2] Energy input (Mcal)	Sorghum silage[2] Units of input	Sorghum silage[2] Energy input (Mcal)	Dehydrated alfalfa[3] Units of input	Dehydrated alfalfa[3] Energy input (Mcal)	Irrig. corn[3] Units of input	Irrig. corn[3] Energy input (Mcal)	Dryland wheat[3] Units of input	Dryland wheat[3] Energy input (Mcal)	Soybean[4] Units of input	Soybean[4] Energy input (Mcal)
Labor (hours/acre)	7.5	18.7	8.0	20.0	8.0	20.0	10.0	25.0	2.0	5.0	3.0	7.5
Machinery (hours)[1]	1.10	50.0	2.80	126.0	2.50	112.5	2.96	133.2	1.67	75.0	1.80	81.0
Gasoline (gal)	15.0	465.8	23.0	714.3	22.0	683.2	26.0	807.4	18.0	559.0	20.0	621.1
Nitrogen (lb)	–	–	–	–	–	–	90.0	225.0	–	–	81.2	203.2
Phosphorus (lb)	80.0	176.0	–	–	200.0	500.0	–	–	–	–	–	–
Seeds for planting (lb)	–	–	40.0	20.0	–	–	30.0	15.2	40.0	16.0	60.0	30.0
Irrigation (Mcal)	–	–	–	–	–	–	–	134.0	–	–	–	–
Pesticides (lb/acre)	1.0	11.0	–	–	1.00	11.0	1.0	11.0	1.0	11.0	0.5	5.5
Drying (Mcal)	–	–	–	–	–	224.0	–	–	–	–	–	–
Electricity (Mcal)	–	–	–	–	–	29.6	–	–	–	–	–	–
Transportation (miles X lb)	10,500	42.0	19,691	78.8	29,400	117.6	16,800	67.2	5,625	22.5	17,550	70.2
Total		763.5		959.1		1,697.9		1,418.0		688.5		1,018.5

[1] Depreciation and maintenance.
[2] Produced on the ranch where it was fed.
[3] Produced in Colorado but transported to the local market place and thence to the ranch where it was fed.
[4] Produced in eastern South Dakota and transported to the ranch where it was fed.

energy equivalent to 15,000 miles of gasoline or about 1,500 gal. of gasoline, which totals about (1,500 x 31,056) 46,584 megacalories (Heichel, 1973). Maintenance alone is estimated to be about twice the depreciation expenditure of cultural energy for farm machinery. Thus for depreciation and maintenance of farm machinery in general it was calculated that 45 megacalories for each hour of usage was considered appropriate for the average piece of large farm machinery over a life span of 6.5 years.

Actual gasoline (gallons used) was estimated on a per hour or per acre basis and charged as cultural energy at the rate of 31,056 kilocalories per gallon, whereas diesel fuel was charged at the rate of 34,783 kilocalories per gallon.

Transportation has been calculated in various ways, but in the present study, transportation off the farm by commercial trucks and to and from the field were combined and charged at 4 kcal/lb/mile. Pimental et al. (1973) suggests that 15 kcal/lb of product will cover transportation to and from the field and to the source of sale. Slesser (1973) states that a truck can move goods 500 miles for 131 kcal/lb. This calculates to be about 3.82 kcal/lb/mile. Pimental et al. (1973) estimates transportation of corn yield in New York to be about 70,000 kcal/acre or about 4 kcal/lb/mile when sold locally or used near the source. This counts gasoline, labor for the driver, and depreciation of the energy content of the machine. In this study much of the produce was actually used at the source of production.

The cultural energy used in irrigation varies considerably, depending upon the type of irrigation. If pump wells are used, the cultural energy is estimated to be about triple that required for stream or ditch irrigation by gravity feed. Slesser (1973) states that irrigation for some cereal crop production in the drier areas may be as high as 20,000 megacalories per acre. Pimental (1973) states that for corn farming where irrigation is used the average input in cultural energy for supplementary water is about 905.6 megacalories per acre. In many areas of the east where corn is raised, only small amounts of irrigation water are used, but in the west substantial quantities of supplemental water are required for corn production. Since irrigation of corn used in this study came from gravity-fed water out of the South Platte river and additional labor, machinery, and gasoline are included in separate categories, an average of only 34 Mcal per acre for irrigation of corn was used. This would be the cultural energy charged against reservoir, channel, and ditch construction.

Table 2. Average yield and cultural energy per pound produced for the feed crops used in the supplements and rations in the six management systems.

Crop	Yield (lb/acre)	Cultural energy input (kcal/lb)
Alfalfa	6,000	202
Sorgham silage	11,252	144
Dehydrated alfalfa	5,600	484
Irrigated corn	4,480	432
Dryland wheat	1,500	459
Soybean	1,560	653

An average active man requires from 2,500 to 3,000 kilocalories per day, and for hard labor about 5,000 kilocalories. In the present study it was estimated that the average farm hand works 8 hours per day and requires at least 4,000 kilocalories. It was further estimated that for every kilocalorie of food consumed 5 kilocalories of cultural energy were required to produce, process, and transport it for consumption. Actually, from 7 to 10 kilocalories of fossil fuel are required to produce 1 kilocalorie of table food, but some of the food is raised on the ranch. Therefore, about 2,500 kcal (4,000 kcal x 5 ÷ 8) of cultural energy are required per man hour of labor on the farm or ranch.

The literature (Pimental et al., 1973; and Heichel, 1973) and correspondence with chemical companies suggest that most pesticides require about 11,000 kilocalories per pound in their manufacture, transport, and application in common agriculture usage for the control of insects and weeds. If the application of the herbicide required 4,000 kilocalories per acre, 2 pounds of pesticide could be applied for 18,000 kilocalories per acre.

Results

Cow Weights

Cows in confinement that were wintered on 6½ lb TDN (Total Digestible Nutrients) lost approximately 4% more body weight from December to May than those fed 8½ lb TDN. Compensatory gains were more rapid during May and June for the cattle wintered at the low nutrition level regardless of whether they went to grass or were left in drylot and fed 14 lb TDN until after breeding.

Weaning Weights

The heaviest weaning weight of calves, 460 lb, came from the drylot cows that received 8½ lb TDN per day. This group was followed by the total confinement group fed 6½ lb TDN whose calves were early-weaned and weighed 417 lb. Both range groups weaned calves weighing 414 lb and the partial confinement group that received the higher nutrition levels produced weaner calves weighing 411 lb (Table 3). The total confinement cows wintered on 8½ lb TDN had a 97.4% calf crop at weaning, thus producing 448 lb per breeding cow. The early-weaned calves from the confinement cows receiving 6½ TDN during the winter had a 94.5% calf crop, with an adjusted average weaning weight per cow of 394 lb.

Table 3. Adjusted weaning weight of calves from three management systems.

Management system	Calf weaning weights (lb)	Weight of calf weaned per cow bred (lb)
Total confinement		
6.5 lb TDN per day	417	394
8.5 lb TDN per day	460	448
Partial confinement		
6.5 lb TDN per day	404	392
8.5 lb TDN per day	410	396
Range grazed		
1 lb alfalfa/day winter supplement[1]	414	393
2 lb alfalfa/day winter supplement[1]	414	397

[1] Fed December 1 to May 1.

Cultural Energy for Range Livestock

The cultural energy for range cows was calculated according to the best estimates of management on the experimental ranch in eastern Colorado. The operation was based upon a 250-cow unit where cows are left on the open range yearlong and receive only a supplement during the winter from December 1 to May 1 (Table 4). Just prior to and during the early part of the breeding season, both range groups were fed a concentrate supplement for 2 to 3 weeks at the rate of 2 lb per day. The cultural energy used in producing feeds and transportation was calculated according to the source of the feed and for the labor and transportation to obtain and feed it, as presented in Table 1. The range cattle required 2.48 and 2.61 Mcal of cultural energy per pound of calf weaned for the cows wintered on 1 and 2 lb of supplement, respectively.

Cultural Energy for Confinement Feeding

An estimated 90 man hours; 105 machine hours involving one 2-ton truck, grinder, mixer, and a tractor loader to clean lots; and 525 gal. of gasoline per month were required to feed 250 head of cattle in confinement. The calculated cultural energy in labor and machinery to feed 250 brood cows in confinement for 30 days was 21,255 megacalories or about 85 megacalories per cow month. In like fashion, an additional 34 megacalories per month of cultural energy in labor and machinery were required to creep feed the calf.

The cows in total confinement required 7.26 and 7.53 Mcal of cultural energy per pound of calf weaned for the 6.5 and 8.5 lb TDN feed level, respectively; and the semiconfined cows produced a pound of weaner calf at an expenditure of 3.98 and 4.53 Mcal of cultural energy for the low and high level of feeding, respectively.

Comparison of Six Feeding Systems

Animal production for each of the six feeding systems was compared on the basis of a 250-cow operation. The production year was divided into four seasons depending on phase of animal production and availability of range forage: October 16 to April 17, April 18 to June 17, June 18 to August 17, and August 18 to October 15.

The average calving date was April 17, the end of the first season. The live weight of calves produced at this time was calculated as the average birth weight (70 lb) times the number of cows (250 head) times the percent calf crop (Table 5). During the remaining seasons, live weight depended on daily gain and death loss that occurred in the separate systems.

Since the weaner calves weighed from 410 to 460 lb, a dressing percentage of 57.9% was used and the fat content was assumed to be 11.2% and the protein was assumed to be 16.6% (Schwartz, 1972). Energy in body fat was calculated as having 9.4 kcal per gram and body protein as having 5.7 kcal per gram.

Digestible Energy/Energy of Meat Produced

A comparison of the various systems of management showed that digestible energy in the feed or forage converted to energy in meat of weaner calves was most efficient for the low nutrient level of total confinement (Table 5). This is believed a result of weaning the calves after 90 days of age and feeding them a growing ration. The two range groups produced the lowest return of food energy in dressed calf meat per unit of digestible energy consumed largely because some of the energy was utilized in foraging. In addition the range forage

Table 4. Average cultural energy input for a 250 cow ranch where alfalfa pellets are fed as a supplement on the range at 1 and 2 lb per day per head respectively from December 1 until May 1, and grain is fed for 16 days during beginning of breeding season. Calculated as a yearlong operation.

Input: Kind	Input: Unit of measure	Alfalfa fed, One lb/day: Units of input		Energy per unit (kcal)		Total energy input (Mcal)	Alfalfa fed, Two lb/day: Units of input		Energy per unit (kcal)		Total energy input (Mcal)
Labor	hours	2,737	X	2,500	=	6,842	2,737	X	2,500	=	6,842
Machinery	hours	1,744	X	45,000	=	78,480	1,744	X	45,000	=	78,480
Gasoline	gallons	3,959	X	31,056	=	122,951	3,959	X	31,056	=	122,951
Transportation	ton miles	2,639	X	8,000	=	21,114	3,149	X	8,000	=	25,192
Supplements											
Alfalfa pellets	pounds	37,500	X	290	=	10,875	75,000	X	290	=	21,750
Grain	pounds	8,000	X	458	=	3,664	8,000	X	458	=	3,664
Total						243,926					258,879

Table 5. Average nutrients and cultural energy used in producing food energy (gross energy) and protein under three management systems with two levels of nutrient intake for each system.

		Confinement		Partial		Range	
Item	Units	6½ lb TDN	8½ lb TDN	6½ lb TDN	8½ lb TDN	1 lb Alfa.	2 lb Alfa.
Number calves by season[1]							
1	number	235	248	242	242	240	248
2	number	235	248	242	242	240	248
3	number	233	240	242	238	233	233
4	number	233	240	238	238	240	230
Dry cows by season[1]							
2	number	15	2	8	8	10	2
3	number	17	10	8	12	17	17
4	number	17	10	12	12	20	20
Live weight by season[1]							
1	lb	16,450	17,360	16,940	16,940	16,800	17,360
2	lb	24,080	27,305	27,235	28,205	29,980	31,820
3	lb	27,453	29,289	28,130	28,280	27,005	26,755
4	lb	30,477	37,932	25,665	25,666	24,430	23,263
Total live weight	lb	98,460	111,946	97,971	99,092	98,215	99,197
Total carcass weight	lb	55,138	62,690	54,864	55,491	55,000	55,551
Avg weaning weight	lb	417	460	404	411	414	414
Digestible energy used	Mcal	1,957,086	2,305,243	2,051,178	2,190,328	2,353,174	2,508,801
Digestible protein used	lb	116,405	119,499	100,692	110,832	95,832	99,666
Cultural energy used	Mcal	715,155	843,166	390,067	448,481	243,926	258,879
Digestible energy not converted	Mcal	1,907,881	2,249,270	2,002,192	2,140,782	2,304,066	2,459,202
Digestible protein not converted	lb	107,253	109,093	91,585	101,621	86,702	60,444
Cultural energy not converted	Mcal	665,950	787,193	341,081	398,935	194,818	209,280
D.E. input/G.E. output[2]	–	39.77	41.18	41.87	44.21	47.93	50.58
D.P. input/T.P. output[3]	–	12.72	11.48	11.06	12.03	10.50	10.81
C.E. input/G.E. output[4]	–	14.53	15.06	7.96	9.05	4.97	5.22

[1] Seasons are: 1 = April 18–June 17; 2 = June 18–August 17; 3 = August 18–October 15; 4 = October 16–April 17.
[2] The ratio of digestible energy input to gross energy output in carcass.
[3] The ratio of digestible protein input to total protein output in carcass.
[4] The ratio of cultural energy input to gross energy output in carcass.

during various periods of the spring and summer while the plants were growing furnished excessive amounts of digestible energy for lactating cows and growing calves, and thus was not used efficiently.

A high protein supplement at the lower level fortified with Vitamin A would have been a better method of supplying nutrient requirements during the winter, which would have used more effectively the digestible energy in the dormant range forage compared to alfalfa (Cook and Harris, 1968).

Digestible Protein/Meat Protein Produced

The two range groups produced more edible protein meat from weaner calves per unit of digestible protein consumed than did other management systems. As can be noted in Table 5, confined groups where calves were weaned early or creep fed were the least efficient systems with respect to protein conversion. This suggests that early weaned calves convert digestible energy effectively but protein rather poorly. In the partially confined groups, it appears that the lower feeding level during winter showed a greater rate of protein conversion than the higher level of feeding.

Cultural Energy/Energy of Meat Produced

As would be expected, the yearlong range grazing system with a winter supplement required considerably less cultural energy than did other systems (Table 5). Range livestock production when sold as weaner calves produced about 1 kcal of dressed-carcass meat for each 5 kcal of cultural energy expended in supplemental feed, machinery, gasoline, and labor for a 250-cow ranching enterprise. Partial confinement, where cows were corralled and fed for 5 months during the winter and grazed on the range duirng spring and summer, produced a kilocalorie of dressed-carcass meat from weaner calves for an approximate cost of 8 to 9 kcal of cultural energy. Total confinement required about 15 kcal of cultural energy for each kilocalorie of dressed meat or about three times as much cultural energy to produce a kilocalorie of edible meat from weaner calf production compared to range calf production.

Optimizing Feeding Systems

The results from the six feeding systems were used to determine the most efficient hypothetical combination of systems under four different criteria as selected by a computer program (Table 5). The first criterion was to maximize feed energy conversion, described as the ratio of digestible energy going into the animals to gross energy from the dressed carcass. The most efficient combination of systems was a low level of feeding in total confinement during the winter, a high level of feeding in total confinement during the spring and summer, and finally grazing the native range from August 18 until October 15. Under such a system, 39 kcal of digestible energy are needed for each kilocalorie of red meat produced. This is only slightly better than the total confinement system with 6½ lb TDN fed daily.

The second criterion was to optimize the efficient use of cultural energy. This criterion was expressed as the ratio of cultural energy used to gross energy in the carcass. The most efficient system in terms of cultural energy expended was the use of range grazing from October 16 to April 17 with animals that received 1 lb of alfalfa supplement daily during the winter. The animals that had received the higher level of range supplement were selected as being most efficient in converting cultural energy to red meat during spring (April 18 to June 17). This efficiency in the use of cultural energy was followed by grazing from June 18 to August 17 animals that had been

Table 6. Selection from 6 management systems by seasons for optimum use of digestible energy and cultural energy in the production of energy in weaner calf meat. Also the selection of management systems for optimum use of digestible protein to produce edible carcass protein along with systems by seasons to produce maximum red meat.

Item	Units	Optimize digestible energy efficiency	Optimize cultural energy efficiency	Optimize digestible protein efficiency	Maximize red meat carcass
Alternative season[1]					
1	–	Confinement 6½ lb TDN	Range 1 lb Alfa.	Range 1 lb Alfa.	Confinement 8½ lb TDN
2	–	Confinement 8½ lb TDN	Range 2 lb Alfa.	Confinement 6½ lb TDN	Range 2 lb Alfa.
3	–	Confinement 8½ lb TDN	Partial 8½ lb TDN	Confinement 8½ lb TDN	Confinement 8½ lb TDN
4	–	Partial 6½ lb TDN	Partial 6½ lb TDN	Partial 6½ lb TDN	Confinement 8½ lb TDN
Number of calves by season[1]					
1	number	235	240	240	248
2	number	228	226	238	248
3	number	228	226	238	240
4	number	228	226	238	240
Dry cows by season[1]					
2	number	15	10	10	2
3	number	22	24	12	10
4	number	22	24	12	10
Live weight by season[1]					
1	lb	16,450	16,800	16,800	17,360
2	lb	26,900	31,420	24,220	30,335
3	lb	27,810	26,846	28,987	29,289
4	lb	24,619	25,142	25,661	37,932
Total live weight	lb	95,779	99,431	95,668	114,916
Total carcass weight	lb	53,636	55,681	53,575	64,353
Avg weaning weight	lb	410	425	398	472
Digestible energy used	Mcal	1,881,334	2,329,934	2,276,901	2,373,034
Digestible protein used	lb	96,534	95,071	89,846	119,823
Cultural energy used	Mcal	635,030	243,377	402,720	743,374
Digestible energy not converted	Mcal	1,833,445	2,280,213	2,229,067	2,315,589
Digestible protein not converted	Mcal	87,630	85,828	80,953	109,141
Cultural energy not converted	Mcal	587,147	195,655	354,886	685,929
D.E. input/G.E. output[2]	–	39.29	46.86	47.60	41.31
D.P. input/T.P. output[3]	–	10.84	10.29	10.10	11.22
C.E. input/G.E. output[4]	–	13.26	4.91	8.42	12.95

[1] Seasons are: 1 = April 18–June 17; 2 = June 18–August 17; 3 = August 18–October 15; 4 = October 16–April 17.
[2] The ratio of digestible energy input to gross energy output in carcass.
[3] The ratio of digestible protein input to total protein output in carcass.
[4] The ratio of cultural energy input to gross energy output in carcass.

wintered on a high level of nutrition under confinement (8½ lb TDN). The fourth system for greatest efficiency in use of cultural energy consisted of grazing cows that had been wintered on the low level of nutrition (6½ lb TDN) and now had their calves by their side and grazing on the range with the yearlong range cattle. These systems by periods used the least amount of total cultural energy and required the lowest quantity of kilocalories of cultural energy (4.91) per kilocalorie of meat produced. This was only slightly better than the low level of supplementing range cows, which required 4.97 kcal of cultural energy per kilocalorie of meat in the dressed carcass.

The third criterion was to maximize the use of digestible protein in the feed for the production of protein in the dressed carcass. The most efficient use of feed protein in the winter resulted from supplementing the range cattle with 1 lb of alfalfa. The second period, from April 18 to June 17, shows that the total confined cows on the low level of nutrition (6½ lb TDN) was selected by the computer. During this period, however, both total confined groups received 14 lb of total digestible nutrients. This selection is understandable because the high level of TDN for the group previously fed a low level of nutrition would make compensatory responses and therefore use digestible protein more efficiently.

During the summer and fall the selection of the management systems for greatest efficiency of protein utilization in the computerized theoretical feeding system was the same as for greatest efficiency in the use of digestible energy. It required 10 lb of digestible protein to produce 1 lb of edible protein in a weaner calf carcass by the most efficient management systems for utilization of feed protein. Again, this was only slightly more efficient than the two range groups.

The fourth criterion was to maximize red meat production. The high level of nutrients fed during the winter under confinement was selected by the computer. This was followed during the spring by the grazing animals that had the highest level of range supplements during the previous winter. The summer and fall management system for greatest red meat production was the high level of nutrient intake for total confinement, which was 14 lb TDN during these two periods prior to weaning. These management systems produced a maximum of 472 lb live weight per calf and a total of 114,916 lb live weaning weight for the 250 breeding cows.

The feeding systems selected by the computer and discussed are hypothetical. Actual experiments are needed to determine if the proposed systems actually are more efficient than those studied. In some cases the proposed "efficient" systems differed only slightly in the selected criteria from the systems studied.

Summary

Six feeding and grazing systems were analyzed to determine the cultural and digestible energy expended to produce a kilocalorie of table meat from weaner calves and the digestible protein consumed to produce a pound of red-meat protein.

Two groups were run on open range yearlong, with one group receiving 1 lb and the other receiving 2 lb of winter supplement per day. Two groups were run on open range for 7 months during spring and summer but confined during fall and winter with a low and high level of confined feeding. The third system involved two groups which were fed in total confinement: group one received 6½ lb TDN/day yearlong except from April 16 to July 18, when they received 14 lb TDN, after which the calves were weaned and fed a growing ration; the other group received 8½ lb TDN/day from October 15 to April 15 and 14 lb/day from April 16 to October 14.

Digestible energy was converted most efficiently by the cows receiving the low level of nutrients in total confinement, because the calves were weaned at 90 days of age and fed a growing ration. The range groups were least efficient in converting digestible energy into gross energy in meat of weaner calves, because digestible energy was excessive in spring and early summer range forage and was therefore wasted.

The yearlong range groups required the least amount of cultural energy to produce a kilocalorie of table meat and the total confinement groups required the most. The semiconfinement groups required almost twice as much cultural energy and the total confinement groups required three times as much cultural energy to produce a kilocalorie of dressed carcass meat compared to the range grazing system.

Digestible protein utilized to produce a pound of protein in red meat was highest in the lower feeding level of total confinement where calves were weaned early and fed a growing ration and most efficient in the lower level of supplementation for the range groups.

A computer program selected the various seasonal feeding systems for optimization of conversion of digestible energy, cultural energy, and total protein in the feed for hypothetical feeding procedures. Also, a hypothetical management system was selected from the six feeding systems studied for the maximization of total production of carcass meat.

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