Effect of Energy and Protein on Reproductive Performance in Beef Cattle

Kirk E. Johnson, DVM*
Thomas J. Evans, DVM**

Introduction

Beef cattle rank first in cash receipts in 21 states and are among the top five income-producing agricultural commodities in 47 of the 50 states. Estimated losses from infertility in cattle exceed by more than 5X the cost of the next most costly bovine disease problem. The 37 million beef cows in the U.S. in 1978 weaned only 27.4 million calves, or 74% of the total possible.[1]

The goal of beef cow/calf production is to maximize the net calf crop--the pounds of calf produced per cow in the herd--in the most economical manner possible.[2] Many factors influence productivity, but one of the keys is to achieve a high level of reproductive performance, and a very important part of successfully accomplishing this is a sound nutrition program.[3]

Factors Influencing Reproductive Performance

Reproductive efficiency encompasses numerous parameters. It involves more than just the conception rate. It includes the ease with which a cow calves,[2] time of year when she calves,[3,4] the percentage of cows breeding early.[2,3,4] It also includes as high a conception rate in as short a breeding season as possible.[2,3,4,5]

In the beef industry we need to realize that in every area of the U.S. there is an optimum time to calve.[3,4] Data in Table 1 shows that in South Dakota calving in February and March maximizes calf average daily gain (ADG). Calves born later than this period of time had lower ADG's and lighter weaning weights.

Table 1. Effect of Month of Birth on 190 day Weight of Beef Calves (S.Dak.)

Month of Birth	Number of Calves	Pre-Weaning ADG	190 Day Weaning Weight
February	108	2.07 lb./day	464 lbs.
March	710	2.00 lb./day	451 lbs.
April	979	1.91 lb./day	434 lbs.
May	351	1.86 lb./day	424 lbs.
June	124	1.77 lb./day	407 lbs.

In many commercial beef operations long calving seasons and poor nutrition programs prevent a high percentage of the cows from cycling and breeding early.[3,5] In data collected from three Kansas herds, the percent of cows observed in heat the first 21 days of the breeding season ranged from 98% for the short breeding season to 35% for the long breeding season (Table 2).[3]

*Dr. Johnson is a 1990 graduate of the College of Veterinary Medicine.
**Dr. Evans, formerly an adjunct instructor of Veterinary Clinical Sciences at Iowa State University is currently in private practice in Plymouth, Nebraska.

Table 2. Reproductive Performance of Three Kansas Cow Herds

	Herd 1	Herd 2	Herd 3
Number of Cows	41	40	40
Length of Breeding Season	45 days	107 days	135 days
Percent Cows Cycling by:			
- 21 days of breeding season	98%	45%	35%
- 30 days of breeding season	98%	58%	50%
- 45 days of breeding season	100%	68%	---

The time between calving and the start of breeding season also influences the number of cows cycling early. Wiltbank and others reported on the length of time postpartum and the percentage of good-nutrition heifers and cows which were in heat (Table 3).[5,6] These results point out the need for at least 50-60 days between calving and the breeding season. A shortened breeding season serves to tighten up the duration of the calving season, resulting in a more uniform calf crop, while providing the time necessary for cows to resume normal estrus activity. The more uniform calf crop allows more of the replacement heifers to reach the necessary size and age at breeding time. The difference of the length of breeding season on calving pattern is seen in Table 4.[5]

In summary, a reproductive program that is timed for early calving and short duration will: increase average weaning weights, increase the number of heifers calving early, provide a more uniform calf crop, and increase the number of cows cycling early in the next breeding season.[5] These goals emphasize the need for a good nutrition program.

Table 3. Good Body Condition at Calving & % Cycling in the Postpartum Period

	% Cycling	
Days Postpartum	1st calf Heifers	Cows
40	15	30
50	24	53
60	47	72*
70	62	82
80	68	89
90	69	94

* 91% of good-condition cows were reported cycling at 60 days by Rice.

Table 4. Calving Pattern of Cows that Calved as an Indicator of Early Conception in the Breeding Season

	Calving Pattern			
	90 day breeding season		45 day breeding season	
% born	1st Calf Heifers	Cows	1st Calf Heifers	Cows
1st cycle	57.8%	32.7%	78.4%	65.8%
2nd	34.5	46.9	21.6	29.2
3rd	6.5	17.8	0.0	5.0
4th	1.2	2.6	0.0	0.0

The Role of Energy and Protein on Cow Herd Reproduction

Energy/TDN. Energy should be the first nutrient to consider in a cow herd nutrition program. Since beef cow nutrition is based on utilization of roughage and grain production residues, energy also represents the major feed ingredient expense. The role of energy in a cow herd nutrition program has been well documented in many research trials over the years. Proper energy balance plays an extremely important role in reproductive performance, calf weaning weights, and in the overall productivity per cow.[3,4,5,8,10,11]

Factors to consider in determining the energy requirements of a cow herd are: 1) cow stage of production, 2) cow frame size, 3) level of milk production, 4) cow body condition, 5) cold weather stress, and 6) the age of the cow.

1) Stage of production. It is useful to consider stage of production in four periods (Table 5).[2,3,7] Table 6[19] illustrates the nutrient requirements for an 1100 lb. cow during each of the four periods.

Table 5. Beef Cow Year by Periods

	Period 1	Period 2	Period 3	Period 4
Length of period	82 days	123 days	110 days	50 days
Stage	post-calving	pregnant and lactating	mid-gestation	pre-calving
Calving Date	April 1	June 22	October 23	February 10

Table 6. NRC Requirements for a 1100 lb. Beef Cow Producing 15 lbs. of Milk During Each of the Four Periods in the 365-day Beef Cow Year

	Period 1 Post-calving (82 Days)	Period 2 Pregnant and Lactating (123 Days)	Period 3 Mid-Gestation (110 Days)	Period 4 Pre-Calving (50 Days)
TDN (lb/day)	13.2	11.4	9.5	11.2
Protein (lb/day)	2.3	1.9	1.4	1.6
Calcium (g/day)	33	27	17	25
Phosphorus (g/day)	25	22	17	20
Vitamin A (IU/day)	39,000	36,000	25,000	26,000

Period 1: This is the time period when the cow is lactating at her highest level. The cow must also accomplish uterine involution, resume normal estrus activity, and be rebred during this period. This is the *most important nutritional period for the beef cow.*[3]

Extensive research on the effect of feeding various energy levels during the postpartum period were conducted at the Fort Robinson Experiment Station in Nebraska (Tables 7,8,9). The level of energy fed post-calving is shown in Table 7. As can be noted in Table 8, when a low level of energy was fed post-calving, 14% of the cows did not exhibit estrus by 90 days postpartum. In contrast, when a high level of energy was fed post-calving all of the cows had cycled. Even more important than its effect on the percentage of cows cycling after calving was the dramatic effect of postpartum energy levels on conception rate. As is noted in Table 9, the cows receiving the high level of energy had a 60% first service conception rate as compared to 43% first service conception rate for those cows on the low level of energy. A dramatic difference is seen in the percent of cows pregnant versus only 29% of those cows on the low level of energy.[8]

Table 7. Effect of Energy Levels after Calving-Cows

TDN		Pounds TDN	
Before Calving	After Calving	Before Calving	After Calving
High	High	9	16
High	Low	9	8

Table 8. Effect of First Postpartum Estrus

	TDN Level Post-Calving	
	High	Low
Interval to First Estrus	48 days	43 days
% Showing Heat by		
- 50 days after calving	65%	76%
- 90 days after calving	95	86
- didn't show heat	0	14

Table 9. Effect of Energy Post-Calving on Pregnancy Rate

Calving Time To Breeding	From 1st Service (%)	After Breeding 20 days	After Breeding 90 days (%)	Pregnant Cows Not Showing Heat (%)
Losing Weight (8 lbs. TDN)	43	29	72	14
Gain Weight (16 lbs. TDN)	60	57	82	0
Difference	17	28	10	14

Period 2: During this period, the cow should be in the early part of pregnancy, while still lactating and maintaining a calf. It is also during this period that the cow should be gaining weight and laying on some energy reserve to prepare for the winter months, assuming a spring calving season.[2,3]

Period 3: This is the period that follows the weaning of the calf and is referred to as mid-gestation. The beef cow must maintain her body weight and the growth of the developing fetus. During this period, the beef cow's nutrition needs are at the lowest level of any stage of the year.[2,3]

It should be remembered, however, that this is also the *easiest time to put weight on the cow* to get her ready for winter. Weaning in early to mid October will allow time to regain proper body condition if necessary. Cows going into winter in good condition take 10 to 15 percent less feed than thin cows.[7,9,19,21]

Period 4: Ensuring next year's calf depends to a great extent on meeting the nutritional requirements of the cow during the last trimester of gestation for this year's calf. Viability and vitality of this year's calf also depend on the maternal nutritional status during this period.[4]

Numerous research trials have documented that when a nutritional deficiency occurs, reproductive performance is affected.[2,3,8,10,11] The level of prepartum nutrition (both protein and energy, but most notably energy), has a major impact on how soon the cows will cycle after calving (Table 10).[8]

Table 10. Effects of Prepartum Nutrition on Return to Heat in Beef Cows

Feeding Level (All at 16# TDN Postpartum)		% Cows Showing Estrus After Calving	
	50 days	70 days	90 days
Low (4.5# TDN)	25%	70%	85%
High (8# TDN)	65%	90%	95%

Table 11. Effect of Malnutrition on Colostrum and Immunoglobulin Production Postpartum

		Adequately Fed Cows	Inadequately Fed Cows
Body Weight at Calving (lbs)		1040	760
Condition at calving		good	thin
Colostral Ig concentration	IgG	57	56
immediately after	IgM	5.2	6.4
calving (mg/ml)	IgA	5.4	7.0
Total Colostrum			
produced in 1st 6 hrs	mean	2500	1200
after calving (ml)	range	1700-4900	150-1900
Total Ig secreted in the			
1st 6 hrs after calving (gm)		144	76

Cows underfed energy during the prepartum period produce less colostrum, lower quality colostrum (Table 11), and less milk, which can have a dramatic effect on mortality, morbidity and subsequent growth rate of the calf.[1,4,10] The single most important factor in preventing neonatal disease is to ensure that the calf receives adequate quantities of good quality colostrum as soon as possible after birth. When calves receive less than 90 grams of total colostral immunoglobulins and are exposed to a pathogenic agent, they will develop an acute, severe diarrhea and, regardless of treatment, will generally die. Thus, inadequate nutrition during the prepartum period dramatically increases the incidence and severity of disease in calves exposed to pathogenic organisms.[4]

The results of a study where cows received a diet meeting only 70% of their energy needs during the last 100 days prepartum are shown in Table 12. Low level dietary energy 30 days pre-calving reduced birth weight, calf livability, cow's milk production, and calf weaning weight while increasing both the number of health problems in the calves and the length of time from calving to 1st postpartum estrus.[10]

Several studies have reported that prepartum nutrition level can alter birth weight although not enough to consistently affect dystocia.[2,10,12,13] In general, increased birth weight has been associated with increased weaning weights, which are probably a function of both additional milk production by the cow and the fact that larger birth weights are associated with faster rates of gain to weaning.[2,12]

Reported effects of prepartum nutrition on conception rates have varied. Some studies have shown that cows that lose weight during gestation but then compensate greatly in weight gain during the postpartum period will actually have higher conception rates (Table 13).[3,8]

Table 12. Effect of Prepartum Energy Levels on Cow Productivity

	Continuous Low Energy Level	Elevated Energy Level for Last 30 Days prepartum
Level of energy		
- lbs if TDN 1st 70 days of 100 day prepartum period	4.84	4.84
- lbs of TDN last 30 days of pre-calving	4.84	10.60
Weight change		
- 1st 70 days (lbs)	-120	-115
- Last 30 days (lbs)	-23	+93
Birth weight of calf (lbs)	59	67
Calf survival		
- at birth	90.5%	100%
- at weaning	71.4%	100%
Calves treated for scours	52.0%	33.4%
Cows milk production (lbs/day)	9.0	12.0
Weaning weight (lbs)	294.0	320.0
In estrus by 40 days after calving	37.5%	47.6%

Table 13. Effect of Energy Level on Conception Rates

Feeding Level (pre-post partum)	Bred not Conceiving	Service Conceived By 1st	2nd	3rd	Services/ Conception
High-high	5%	67%	95%	95%	1.55
High-Low	10	42	74	84	2.35
Low-high	0	65	75	100	1.60
Low-low	33	33	50	67	3.00

2) Cow size. In the past 10 years, research has focused on the relationship of cow size and breed to production efficiency. Some investigators have reported that breed and associated size may have an impact on the maintenance requirements of cows (Table 14[14]),[14,15] while others have reported that the amount of energy required per pound of calf weaned will be fairly constant, and not influenced by size or breed.[3,16,17,18] Most of this information was based mainly on output characteristics such as digestible energy to dam per lb. of calf weaned (Table 15).[16]

Table 14. Estimates of Metabolizable Energy Required for Maintenance of Various Breeds or Breed Crosses

Breed or Breed cross	Physiological State	Maintenance kcal * $kg^{-.75}$ * d^{-1}
Angus-Hereford	Nonpregnant, nonlactating, 9-10 yr	130
Charolais X	" " "	129
Jersey X	" " "	145
Simmental X	" " "	160
Angus	Nonpregnant, lactating, 5-6 yr	149
Hereford	" " "	141
Simmental	" " "	166
Charolais	" " "	165
Angus	Nonpregnant, nonlactating, 5-6 yr	118
Hereford	" " "	120
Simmental	" " "	134
Hereford	Growing-finishing, 9-15 mo	106
Simmental	" "	126
Angus-Hereford	Pregnant, lactating 8-9 yr	151
Red Poll X	" " "	157
Brown Swiss X	" " "	156
Gelbvieh X	" " "	158
Maine Anjoe X	" " "	146
Chianina X	" " "	174

Table 15. Feed Utilization by Two-Year-Old Crossbred Cows

	Breed Cross			
	Angus X Hereford	Angus X Charolais	Angus X Jersey	Angus X Simmental
No. of Cows	25	28	25	29
1st service conception (%)	68	79	72	72
Total conception (%)	92	85	100	93
Calves weaned (%)	92	96	84	97
Weaning weight (lbs)	482	515	488	517
Digestible energy of dam/lb calf weaning weight (Mcal)	9.2	9.5	9.3	9.4

According to NRC recommendations, as cows increase in weight, each 10% increase in weight is accompanied by an approximate 6-7% increase in required energy level.[2,19] Work done at Clay Center, Nebraska showed differing results. The larger, growthier, heavier breeds have a higher energy requirement per pound of body weight for maintenance than medium and smaller framed breeds of cattle (Table 14).[14] Miller, et al. at Iowa State have utilized these findings and incorporated a 15% increase in pound per pound maintenance requirement in their computerized *Beef*

Cow Ration Analysis Program for exotic and exotic cross cows. However, in this program, Charolais are not in the exotic list.[15] Maintenance requirements appear to increase with increased potential for growth rate, as well as with increased potential for milk production. Thus, the larger, growthier cattle may have less advantage or be at a disadvantage in an environment that may restrict their capabilities.[14]

3) Level of Milk Production. As with increased frame size, the cattle industry has been selecting for increased milk production. Unfortunately we often do not take into account how much effect the increase in milk production will have on TDN and protein requirements. As shown in Table 16, going from a cow producing 11 lbs. of milk to one producing 22 lbs. of milk without any alteration in the cow's size, increased the TDN requirement by 28% and the crude protein requirement by 42% during the early postpartum period.[3]

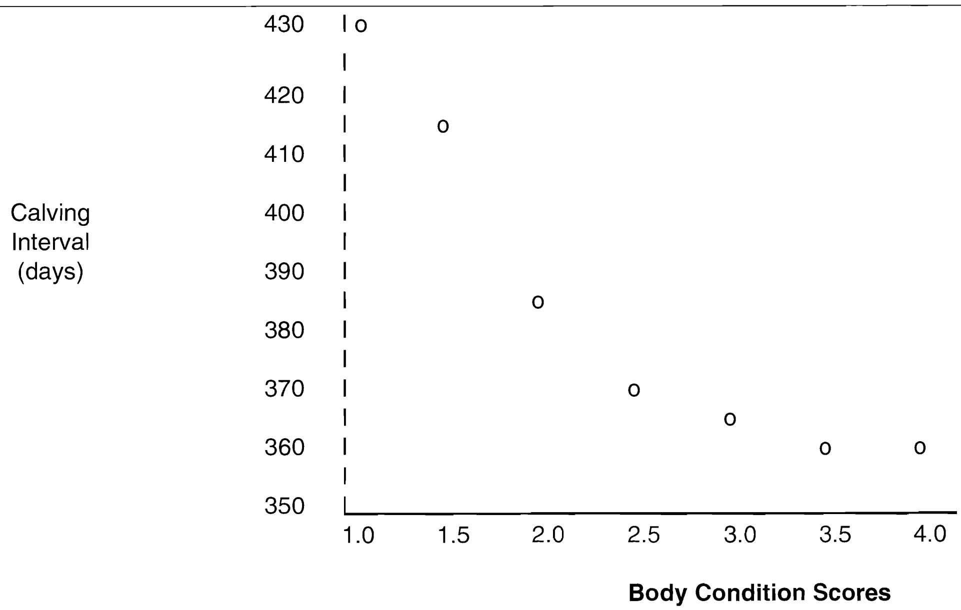
4) Body condition. Reproductive efficiency in beef herds will improve by evaluating body condition as a criterion for determining nutritional status, since body condition score (BCS) at calving is a direct measure of prepartum nutritional status.[4]

The calving interval has been shown to be negatively correlated with body condition (Table 17).[20] As BCS decreased (one being thin, and four in medium condition), the calving interval increased.

Table 16. Effect of Milk Production on Nutrient Needs

	Level of Milk Production		Percent
	11 lbs.	22 lbs.	Increase
TDN	11.0	14.1	28%
Crude Protein	1.9	2.7	42%

Table 17. Relationship Between BCS at Mating and the Calving Interval in Beef Cows



A significant relationship has been shown between BCS at calving and subsequent pregnancy rate. Only 72% of cows that were thin at calving were pregnant after an 80 day breeding season that began 82 days after the first cow calved. This compares to 89 and 92%, respectively, of cows in moderate and good condition at calving being pregnant after 80 days of breeding. Note also the decrease in cows pregnant in early breeding season when they were thin at calving (Table 18). Most of the cows in moderate and good condition at calving returned to estrus by the start of breeding season (Table 19). There must be adequate condition on the cow at parturition if we expect her to be in estrus within 80 days after calving.[4]

Spitzer at Clemson University reported on an on-going project involving 130 cows over 2 years; the results being depicted in Table 20. All of these cows received a high level of nutrition in the last trimester of gestation and calved with moderate to good BCS. A high proportion showed estrus early in the breeding season regardless of how they were fed postpartum.[4]

Table 18. Effect of Body Condition at Calving on Rebreeding

Condition	Percent Pregnant After Breeding	
at calving	20 days	80 days
Thin	25	72
Moderate	35	89
Good	39	92

Table 19. Cows Showing Estrus as Related to BCS at Calving

			In Estrus Postpartum (cumulative %)			
Condition at Calving	40 days	50 days	60 days	70 days	80 days	90 days
Thin	19	34	46	55	62	66
Moderate	21	45	61	79	88	92
Good	31	42	91	96	98	100

Table 20. Effect of Postpartum Nutrition on Occurrence of Estrus When Cows Calved with Moderate to Good Condition

	In Estrus Postpartum (cumulative %)		
Group*	20 days	40 days	60 days
High	82	96	100
Moderate	90	97	100
Low	81	91	100
Low-flush	86	96	100

* High: Fed to gain 1.0 to 1.5 lb/day from calving through the breeding season.
Moderate: Fed to maintain body weight from calving through the breeding season.
Low: Fed to lose 1.0 to 1.5 lb/day from calving through the breeding season.
Low-flush: Fed to lose 1.0 to 1.5 lb/day until 14 days prior to the start of the breeding season and then fed a flushing ration calculated to ensure rapid weight gains for a 28-day period.

The key to early return to estrus in beef cows is adequate prepartum levels of nutrition, which results in cows calving in moderate to good BCS. As previously discussed, this is also the key to a healthy calf, and a milk supply capable of supporting heavy weaning weights. However, if the weight loss after calving is sever, even cows calving in good body condition may not cycle or may initiate cyclicity and then become anestrous. These effects are compounded if cows receive low levels of nutrition both before and after calving (Table 13).[4,8]

5) Cold weather. Environmental conditions have a major influence on the cow's nutrient requirements. Unfortunately, too often in our cattle feeding program we fail to consider this aspect.[3] *Effective temperature* is an index of the heating or cooling power of the environment, which includes any factor that alters environmental heat demand, such as solar radiation, wind, humidity, or precipitation.

The major effect of cold temperature on the nutrient requirements of the cow is an increased need for energy and Vitamin A. Most data suggests that needs for protein, other vitamins, and minerals are not altered during cold.[7] When cows are subjected to cold weather that is below the lower critical temperature (the temperature at which rate of performance begins to decline as temperatures become colder), the level of energy must be increased by approximately 1% for each 1° F drop below the critical temperature in order for the cow to maintain weight.[2,3,22] Table 21 gives the lower critical temperatures and increased energy requirements for various conditions.[7]

As temperature drops there is an increase in voluntary feed intake (Table 22). Passage rate increases with increased intake, and as a result roughage digestibility declines (about 1% for every 10° F fall in effective temperature).[7]

The results of not adjusting for coldness (Table 23) are: a decrease in milk production which will give a smaller calf at weaning, and poor weight gain in the last half of gestation which reflects on the lower percent cycling 60 days post-calving.[7]

Table 21. Estimated Lower Critical Temperatures for Beef Cattle and the Increased Maintenance Energy Costs for Cattle per Degree (F) Coldness

Coat Description	Critical Temperature	1100 lb. Cow (% increase/degree coldness)
Summer Coat or Wet	59°F	2.0
Fall Coat	45°F	1.3
Winter Coat	32°F	1.0
Heavy Winter Coat	18°F	0.7

*For animals in sunlight, critical temperature may be increased 5 to 9°F, which is beneficial in winter and detrimental in summer.

Table 22. Change in Voluntary Feed Intake as Temperature Drops

Temperature	Percent Change
41-23°F	Increase by 3-8%
23-5°F	" " 5-10%
Below 5°F	" " 8-25%

Table 23. Results of Adjusting Feed Levels for Cows During Cold

	Ration Adjusted For Coldness	Ration Not Adjusted
Weight Change		
- during last 135 days of gestation	+115 lbs	+26 lbs
- at weaning	-105 "	-119 "
Net Weight Change	+10 "	-93 "
Daily Milk Production	20.3 "	17.5 "
Percent Cycling in 60 Days from Mean Calving Date	82%	65%

6) Age of cow. The age of the beef female will influence the energy requirement and to a greater extent the protein requirement. Young growing pregnant heifers are particularly susceptible to protein-energy malnutrition. NRC standards show that pregnant heifers, because of both growth and maintenance requirements, need considerably more energy and protein than mature pregnant cows (Table 24). If not fed accordingly, *first calf heifers* may be the first animals in a beef herd to exhibit signs of protein-energy malnutrition,[23] which may be reflected in a dramatic decrease in reproductive performance (Table 25).[11]

PROTEIN. The second most important nutrient in a cow herd nutrition program is protein. Protein plays an especially important role in lactation and growing animals. Protein deficiency symptoms include decreased growth and feed efficiency, anorexia, fatty liver, infertility, reduced fetal birth weight, the weak calf syndrome, and reduced milk production. Part of the reason for these effects is that inadequate protein intake will decrease the level of forage cows will consume, and thus alter energy and all other nutrient intake levels.[3,4]

Table 24. Nutrient Requirements of Different Maturity Beef Breeding Females

	Body Weight (lb)	Met. Energy (Mcal/d)	Crude Protein (lb/d)	Dry Matter (lb/d)
Dry Pregnant Mature Cows				
- middle third of pregnancy	1000	14.5	1.3	18.1
- last third of pregnancy	1000	17.3	1.6	19.6
Pregnant Yearling Heifers				
- last third of pregnancy	950	21.3	1.8	20.0

Table 25. Effect of Postpartum Energy Intake on Conception Rate in Two-Year-Old Heifers

Feed Level	Percent Conceived by 120 Days After Calving
Low	64%
Medium	72%
High	87%

It is a common error to overfeed protein to gestating beef cows and underfeed protein to lactating beef cows. In many cases protein supplementation is confused with better nutrition, resulting in energy deficits.[3]

Factors to consider on how much protein to feed to a cow herd are: 1) age of individual cows, 2) stage of production, 3) level of milk production, 4) type of forage being fed.[3]

1) Age of the cow. The age of the beef cow greatly influences the protein requirement. Young cattle that continue to grow and develop need more protein than mature cows (Table 24). For this reason, it is beneficial to have bred heifers separated from the mature cows.

2) Stage of production. Just as previously discussed for energy requirements, the protein requirement is dramatically affected by stage of production. As shown in Table 6, the protein requirement is lowest during Period 3 or mid-gestation period. It increases slowly as the cow approaches calving and then virtually doubles after the cow calves.[3]

If the cows are not fed adequate levels of protein prior to calving, an increased incidence of the weak calf syndrome can be expected. Inadequate levels of protein post calving will result in decreased milk production.[3]

3) Level of milk produced. As previously shown in Table 16, not only does the level of milk production influence energy requirements, but it also greatly influences protein requirements. Increasing production from 11 lbs. of milk to 22 lbs. of milk, is accompanied by a 42% increase in the protein requirement. This reinforces the need to adjust protein in accordance with level of milk produced in our beef cow herds.[3]

4) Type of forage fed. A key factor influencing how much protein must be fed to a herd of cows is the type of forage that is being fed. There is a wide range in the type of forages that can be fed to cows during the wintering period, and protein levels on these forages should always be considered in determining how much supplemental protein to feed.[3] If cows are consuming low amounts of a poor quality protein source, these cows are going to require a higher level of protein supplementation than cows on a higher quality feedstuff. Ingredient availability is highly variable and must be kept in mind when attempting to optimize beef cow production.

Summary

It is obvious that a very integral part of achieving the desired level of reproductive performance in a set of cows is having a sound and complete nutrition program. There are many management factors that can be implemented when a good nutrition program is in place that can further increase the reproductive status of a given herd. When a producer utilizes a short calving season, such as 45 to 70 days, it is easier to plan a sound nutrition program than when the cows calve over an extended period of time. When long calving seasons are used, averages are used in feeding the cows, and in many cases the cows are improperly fed.[3] Not only does meeting the nutritional requirements become easier with a short calving season, but it also allows the cows more time to get back in shape before the start of breeding season. Providing the level of management needed to integrate these steps will increase fertility and overall production of the herd.

References

1. Mickelson WD, Paisley LG. Infertility in beef cows. *Mod Vet Pract.* 6(10):834-839. 1980.

2. Corah LR. Nutrition of beef cows for optimizing reproductive efficiency. *Compend Contin Educ Pract Vet.* 10(5):659-664. 1988.

3. Corah LR. Nutrition and its effect on reproductive performance in beef cattle. *Kansas State University Publication*: 1-14.

4. Spitzer JC. Influences of nutrition on reproduction in beef cattle. In: Morrow DA, (ed). *Current Therapy in Theriogenology 2.* Philadelphia: WB Saunders Co. 320-341. 1986.

5. Prince DK, Mickelson WD, Prince EG. The economics of reproductive beef management. *The Bovine Practitioner.* 22:92-97. 1987.

6. Walters DL, Burrell WS, Wiltbank JN. Influence of exogenous steroids, nutrition, and calf removal on reproductive performance of anestrous beef cows. *Theriogenology*. 21:395-406. 1984.

7. Busby WD. Beef cow nutrition. *Iowa State University Publication.* 1-4.

8. Wiltbank JN, Rowden WW, Ingalls JE, et al. Effect of energy level on reproductive phenomena of mature hereford cows. *J Anim Sci.* 21:219-225. 1962.

9. Eness P, Ruble M. Personal Communication. 2-20-90.

10. Corah LR, Dunn TG, Kaltenbach CC. Influence of prepartum nutrition on the reproductive performance of beef females and the performance of their progeny. *J Anim Sci.* 41:819-824. 1975.

11. Dunn TG, Ingalls JE, Zimmerman DR, Wiltbank JN. Reproductive performance of 2-year-old hereford and angus heifers as influenced by pre- and post-calving energy intake. *J AnimSci.* 29:719-726. 1969.

12. Bellows RA, Short RE, Richardson GV. Effects of sire, age of dam and gestation feed level on dystocia and postpartum reproduction. *J Anim Sci.* 55:18-27. 1982.

13. Bellows RA, Varner LW, Short RE, Pahnish OF. Gestation feed level, calf birth weight and calving difficulty. *J Anim Sci.* 35:185-186. 1972.

14. Ferrell CL, Jenkins TG. Cow type and the nutritional environment: nutritional aspects. *Anim Sci.* 61:725-741. 1985.

15. Miller MM, Strohbehn D, Loy D, Spike P. Microcomputer worksheets for agriculture--beef cow ration analysis. *Iowa State University Publication*:April 1987.

16. Bowden DM. Feed utilization for calf production in first lactation by two-year--old F_1 crossbred beef cows. *J Anim Sci.* 51:304-315. 1980.

17. Klosterman EW, Parker DF. Effect of size, breed, and sex upon feed efficiency in cattle. *J Anim Sci.* 51:304-314. 1980.

18. Dinkel CA. The range beef cow--what size. *Proceedings of the Range Beef Cow Symposium VII*:. 148. 1981.

19. National Research Council (NRC). *Nutrient Requirements of Domestic Animals, No. 4. Nutrient Requirements of Beef Cattle.* Washington, DC: NRC. 1984.

20. Peters AR, Ball PJH. *Reproduction in Cattle.* London: Butterworths. 161-175. 1987.

21. Strohbehn DR. Condition scoring beef cows. *Iowa State University Publication.*

22. Ames DR. Managing cows during winter. *Proceedings of the Range Beef Cow Symposium IX.* 11-16. 1985.

23. Oetzel GR, Berger LL. Protein-energy malnutrition in beef cows. *Proceedings of the AABP.* 18:116-123. 1986.

HollyAnn Johnson