NUTRITIONAL VALUE OF RANGE FORAGE FOR LIVESTOCK

George Ruyle [1]

Grazing is the base of the nutritional program for range cow outfits. On some ranches, range forage is the only feed source cattle have except for salt and water. During periods of initial plant growth in the spring and summer all forage species are high in nutrient content although moisture content may also be high and limit dry matter intake. However, as plant growth stages advance, the nutritional differences among forages becomes more evident, especially during the fall and winter periods.

The nutrient value of range forages is best tested by their ability to provide for the nutritional requirements of the grazing animal during the various seasons of production. Plant nutritional values should be compared with the corresponding animal requirements during the year.

The nutrient evaluation of range forage can be based on how much protein, phosphorus and energy the plants contain. These, along with carotene (vitamin A) are the four principle nutrients that may be limiting on rangelands. These can best be discussed by dividing the plants into three common forage classes, grasses, forbs (broad-leaved, herbaceous plants, often called weeds), and shrubs.

Protein is calculated from the amount of nitrogen contained in plants. Grasses decline in digestible protein rapidly as they mature. Nitrogen is moved by the grass plant from above-ground parts available to the grazing animal to storage organs below the ground as the current years grass growth matures. Shrubs, on the other hand, are good sources of protein even after they reach full maturity because nutrients remain in branches and leaves as well as below ground. Forbs, in general, are intermediate between shrubs and grasses with respect to protein content during most seasons.

Phosphorus, a macro-mineral, is often limiting in range forage plants. Grasses are low in phosphorus soon after they form seed. Shrubs are generally considered good sources of phosphorus for general animal maintenance and gestation, even when mature. Most forbs have a phosphorus content only slightly lower than that of shrubs. Phosphorus content of plants can fluctuate depending on the soil status. Soils high in phosphorus will allow plants to contain more phosphorus than where soils are limiting in phosphorus content.

Energy values of forage are commonly reported as Total Digestible Nutrients (TDN) or Digestible Energy (DE). Grasses are generally considered good sources of energy primarily because of their high content of cellulose. In very rank grasses however, digestibility will be so low as to reduce intake and thereby reduce total energy intake. Digestibility is the proportion of a dietary nutrient available for animal metabolism and indirectly tells us something about intake (as digestibility goes down, intake may go down). Shrubs are not considered good sources of energy after they reach fruit development. Again, forbs are intermediate between grasses and shrubs in furnishing energy. In my opinion, energy is more frequently a limiting factor to livestock production on rangelands than is crude protein. The single biggest problem however, especially when forage plants are mature, is getting enough total nutrients into the animal each day.

Other factors may also affect the nutritive value of range plants. Range condition, for example, may alter total forage intake of grazing cattle. Research shows that protein and phosphorus are about the same in plants growing on good versus poor condition range. However, plant species on poor condition range may be less digestible than plant species on good condition range which can reduce total forage intake by livestock. The animals either can't or won't eat enough. An appropriate mix of grasses, shrubs, and forbs, is necessary to provide nutritious forage to livestock on a year-long basis.

Management factors such as stocking rate and specialized grazing systems can also influence grazing animal nutrition. Heavy stocking reduces individual animal performance and can result in damage to the forage resource. Although the influence of animal numbers can be altered by controlling the time the plants are exposed to grazing and allowing for adequate recovery periods, proper stocking rates are essential to long-term range livestock production levels.

Grazing systems may reduce or improve forage nutritive value. Although forage reserves are a necessary part of ranch planning, and some amount of plant material should be left for resource protection, if pastures are allowed to accumulate a lot of old plant growth animal production may suffer. This can be offset by adjustments in stocking rates or changes in range condition. Carefully planned grazing can help increase diet quality. In grazing cells for example, the longer animals stay in a particular paddock the further diet quality is reduced. If grazing periods are shortened, be sure to consider the implications of the subsequently shorter rest periods.

Supplementation will probably be necessary to achieve high levels of livestock performance from rangelands although economic analysis should consider the bottom line before any decision on supplementing cattle diets is made. Even though total production may be reduced, profits may be maximized at lower input and offtake levels. When determining whether or not to supplement, cow as well as forage conditions should be considered, but remember, it is the nutrients provided by the range forage that are supplemented. Over-supplementation, especially of protein, or supplementing too late in the season to improve production are not uncommon practices.

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RANGE COW NUTRITION MANAGEMENT EVALUATOR

Russell Gum,[1] George Ruyle,[2] Richard Rice,[3] and Eric Schwennesen [4]

INTRODUCTION

Many of the important decisions ranchers make involve the management of the nutritive intake of their cows. Decisions such as levels and timing of supplemental feeding directly impact the level of nutritive intake of cows. Decisions such as choice of breeding date indirectly impact the level of nutrition by changing the timing between the periods of the pregnancy—calving cycle with high nutritive needs and periods of forage availability. This linkage between ranchers decisions and the nutritive intake of range cows is complex and involves many factors. Further, the linkage between the nutritive intake of range cows and their production is also complex. This complexity makes the analysis of decisions impacting nutritive intake of cows a very difficult task.

In order to provide ranchers a tool to analyze decisions which impact range cow nutritive intake, a computer simulation of the range cow nutrition—production process has been developed. This program allows ranchers to predict the results of alternative strategies of managing the nutritional intake of their cows and evaluates the results in economic terms.

The purpose of the range cow nutrition—production simulation is to predict the results of rancher decisions given an observed or predicted diet of the range cow. The simulation tracks the input to the cow and calf on a daily basis, and predicts their weight daily and predicts the calving rate for the cows. The simulation is run for a period of seven years and a summary measure of the present value of the cows production over the seven year period is produced to be used as a yardstick to economically compare different alternatives or conditions.

To use the evaluator, information on the diets of the cows and the nutritive content of the forage they are eating is necessary. The diet data is obtained by microscopic analysis of fecal samples to identify undigested plant cells. The nutrition data is obtained from laboratory analysis of forage samples. Since both diets and the nutritive value of the forage change as the seasons change these analyses must be repeated on a monthly basis. For ranches which have not developed this information the program can still be used by inputting data from nearby ranches or even from ranches in other areas with similar conditions.

Once the diet and forage data are collected and entered into the computer, information on the beginning condition of the cow and on the current management practices, such as breeding dates and supplementation, must be input into the computer. The computer then predicts the performance of the cow for a period of seven years and produces a series of graphs, which are useful in analyzing the results and formulating alternative strategies for the computer to evaluate.

The following is an example of how a rancher might use the program. First the rancher, working with technical help from an extension agent, would develop an estimate of the composition of the diet and the nutritional composition of the forage species in the diet. An example of such information in a graphical form is displayed in Figure 1. The line labelled “1” is the percent of the cow's intake made up of this particular plant species over a complete season. The line labelled "2" is an estimate of the percent phosphorus contained in this particular forage over the season while the lines labelled "3" and "4" are estimates of the protein and TDN percentages. As can be seen in the example, both the percentage of the diet and the nutritional value of the forage vary greatly over the season.

Next the rancher would specify the particular management scheme to be used for the base run. For our example, this is a breeding date of May 15th, an initial weight of 900 pounds for a bred cow, a weaning date of October 15th, and no supplement. The model is then run on the computer with the results as shown in Figures 2 and 3. Figure 2 shows the life production of the cow under the base conditions. As can be seen in the figure, the cow loses weight and the calving rate declines until in the forth year she skips a calf and regains some of the lost weight. After this she again declines in weight and skips another calf in year seven. Figure 3 shows detail of the nutritional situation over the season. The line labelled "1" is the predicted gain per day given the diet and forage nutrition. Line "2" is the gain which would be predicted based only upon the phosphorus content of the forage under the assumption that the other components of nutrition protein and energy were readily available. Line "3" is the predicted gain based on the protein level and line "4" is the predicted gain based on the energy level, again assuming the other components of nutrition are available. The graph demonstrates the fact that energy must be available for gain and that the other components of gain combine with energy to result in gain. At the start of the year energy is very low with the result that the cow loses from one to two pounds a day for the first three months of the year. For the next three months the energy availability improves but the cow continues to lose weight at about one quarter pound per day. After six months the summer rains result in new forage and the cow gains weight until winter. During this four month time of weight gain, it is clear from the graph that while the cow has an excess of energy, protein levels and particularly phosphorus levels are limiting factors in keeping the cow gain below the gain possible if the energy were fully utilized.

The economic results depend upon both calf weights, which are simply a function of the forage available between calving and weaning, and upon the calving percentage of the cow over her lifetime. For the base run the lifetime value of the cow's production expressed in present dollars is 777 dollars under conservative estimates of calf prices. This value will be used as a yardstick to judge alternative management strategies.

One possible reaction to the base results would be to check on the correspondence between forage availability and nutritional needs of the cow. Figure 4 displays how the cow's nutritional requirements change over the annual cycle. Requirements are high during the last trimester of pregnancy and during the time the cow is nursing her calf. After the calf is weaned the requirements drop considerably. Comparing the requirements to the results of the potential and actual gain chart result in the discovery that gain is highest at the time of the year where nutritional requirements are lowest. Since the requirements are tied to breeding date, one possible alternative to evaluate would be changing the breeding date to September 1st in order to better match up requirements and forage availability. Figures 5 and 6 display these results. The most obvious result is that the cow maintains her weight for the seven years and does not skip any calves. The gain graph shows that weight losses are moderated for the winter months caused by reducing the nutritive requirements of the cow during this period. The economic yardstick for this alternative is $1,128. This is improvement over the base case of over 350 dollars all without any additional cost to the rancher.

Another possibility suggested by analysis of the base run is to remove the limitations on phosphorus during the period where it is limiting gain, by supplementing from July 15th through December 31st with a 6% phosphorus block at the rate of .2 pound per day and a cost of 20 cents per pound for the supplement. The results of this simulation are displayed in Figures 7 and 8. A definite improvement in performance over the base run can be observed. The limitation of gain by phosphorus is significantly reduced resulting in higher gains and the economic yardstick adjusted for the costs of the supplement, increases to 964, over a 150 dollar improvement.

What about a more traditional program of supplementation? What happens if we feed 1.5 pounds per day for 95 days beginning on November 1st of a 2% phosphorus, 25% protein and 65% TDN supplement. The results are displayed in Figures 9 and 10. The cows get fat. The calving rate therefore increases. The gains increase dramatically over the base run for the period the cows are being supplemented. The graph suggests that good use of the forage energy is being made with the addition of the limiting factors of phosphorus and protein to the cows diet. Most importantly the economic yardstick increases to 1,283 dollars, even after subtracting out the feed costs, over a 500 dollar increase compared to the base situation.

What about changing both the breeding date and supplementing? What about changing the timing of the supplementation? What about ....? The rancher can continue the process of evaluating alternatives quickly and cheaply by use of the computer simulation. Hopefully the computer results would lead to the selection of alternatives to further evaluate by real world testing and monitoring.

Conclusions

Ranchers in Arizona now have a new tool to help them evaluate decisions involving changes in range cow nutrition. As data bases on diets and forage nutritive values are expanded, ranchers throughout the state will be able to quickly and efficiently evaluate alternative nutrition management strategies. For further information on the Range Cow Nutrition Evaluator contact your County Extension Agent.

The authors are all members of the Integrated Range Livestock Management team, College of Agriculture, The University of Arizona.

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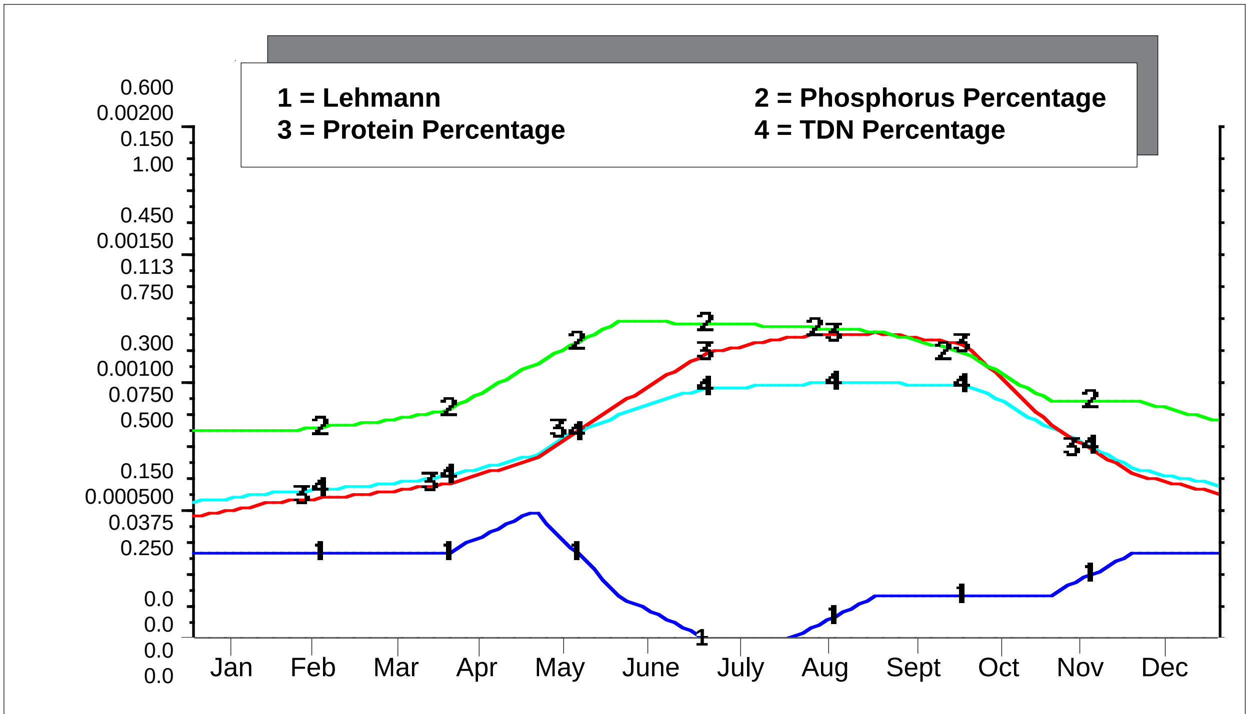


Figure 1

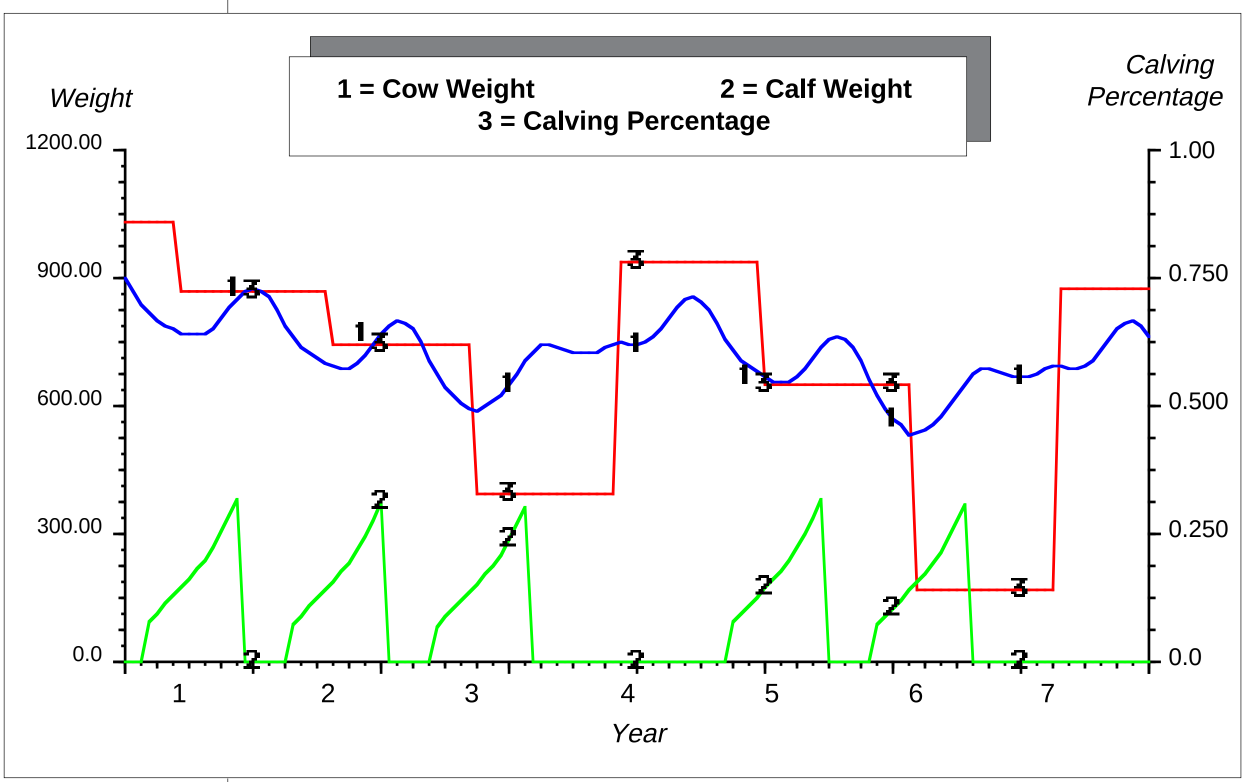
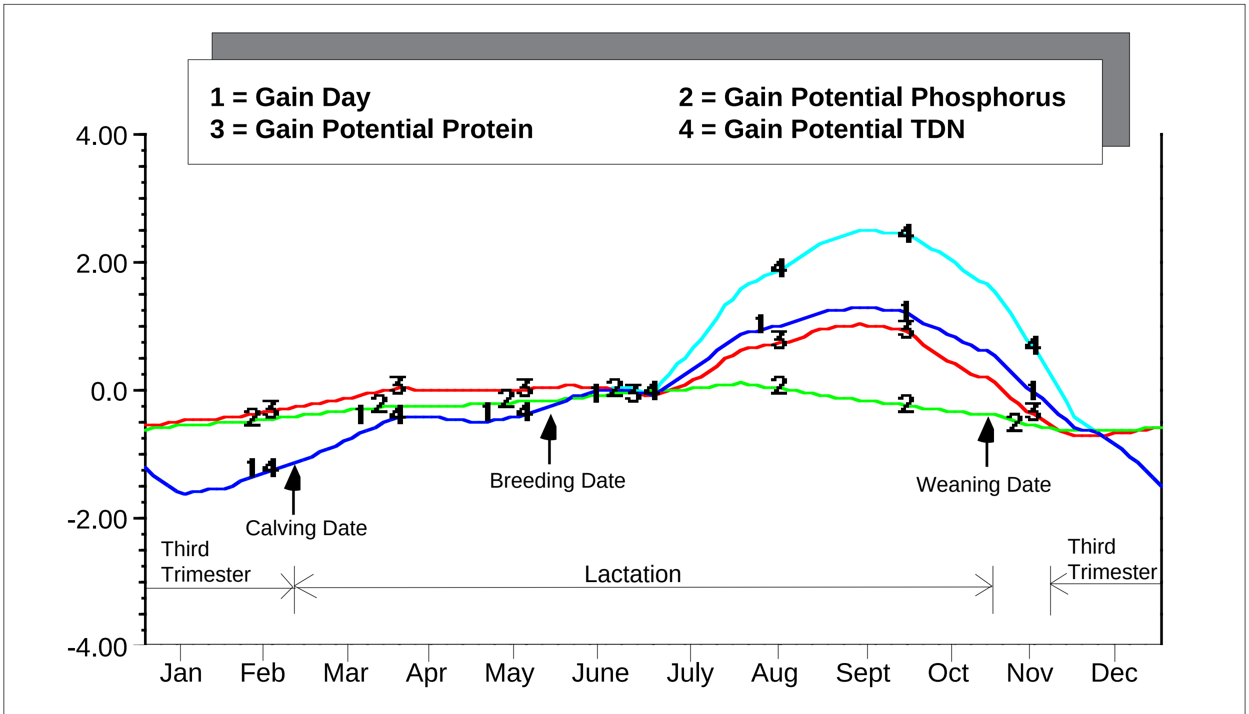


Figure 2



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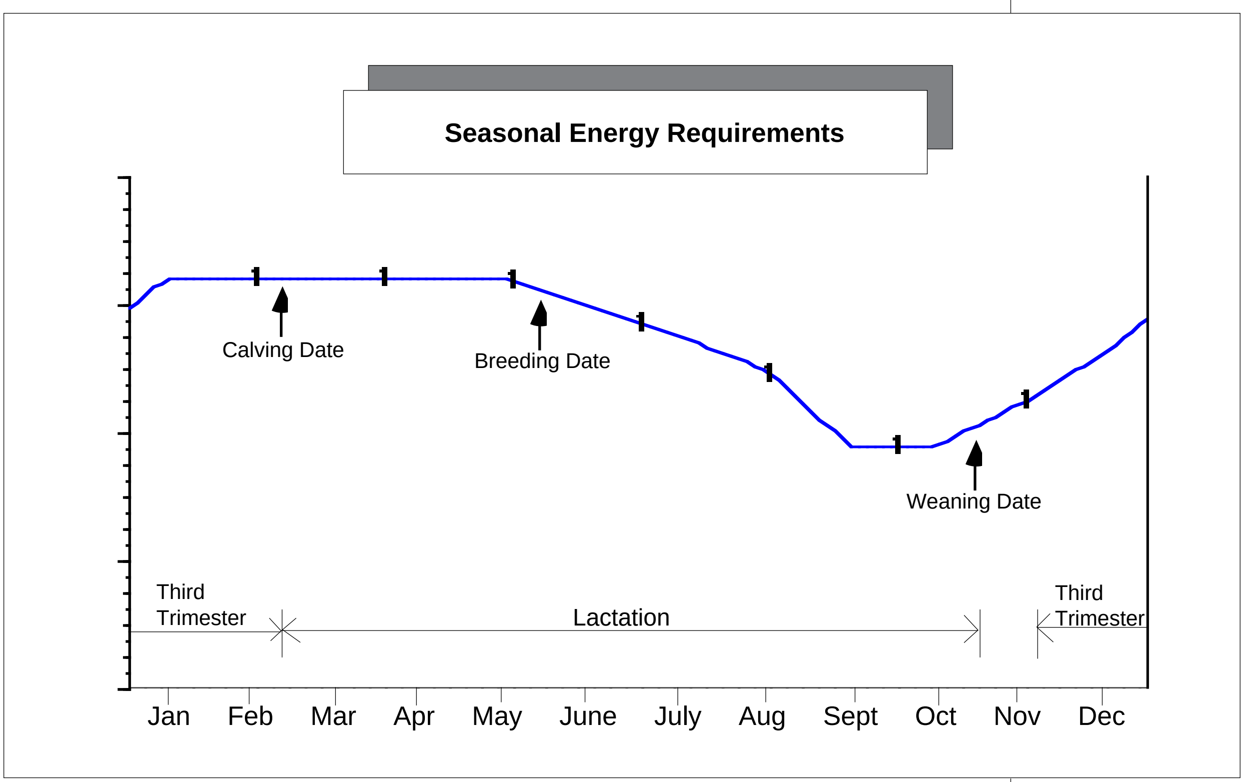

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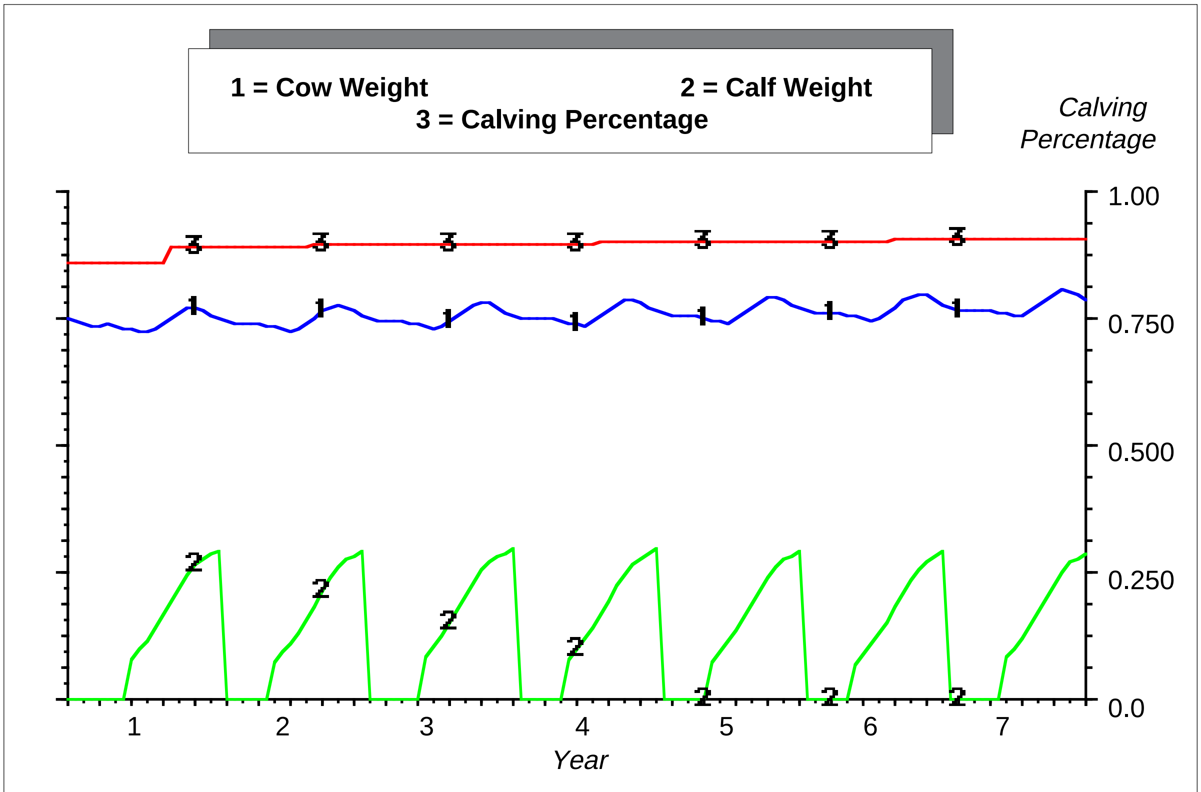
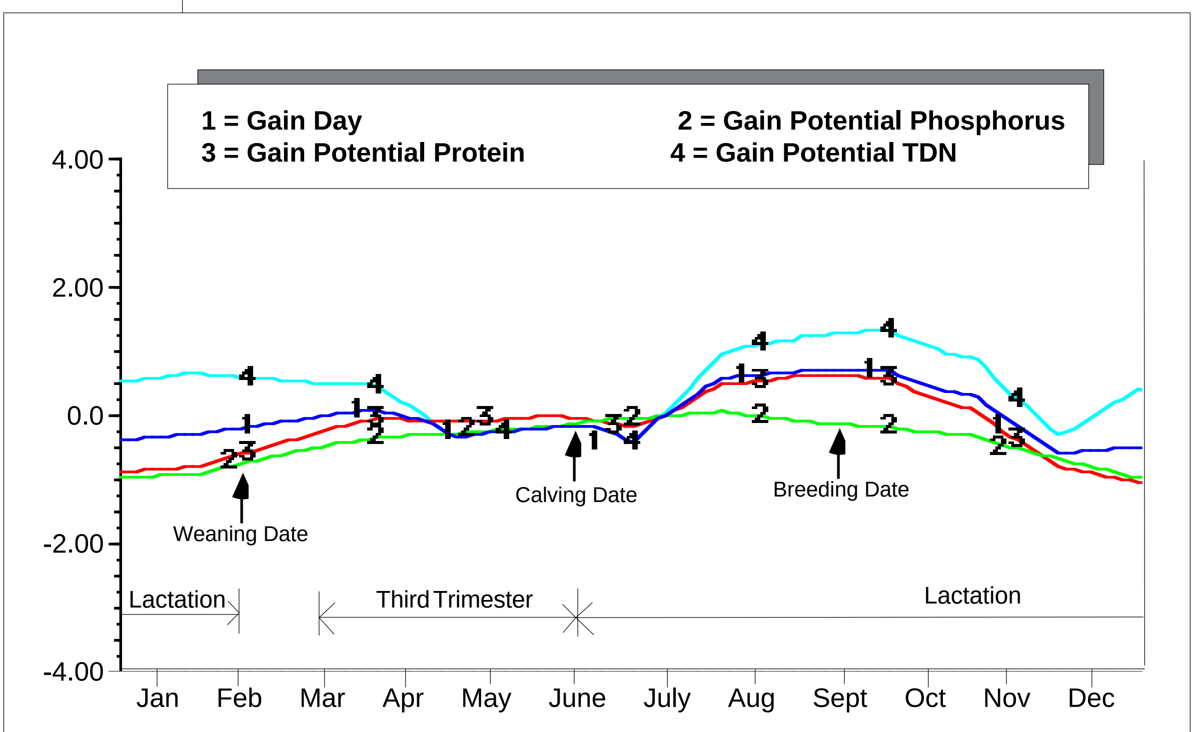


Figure 5



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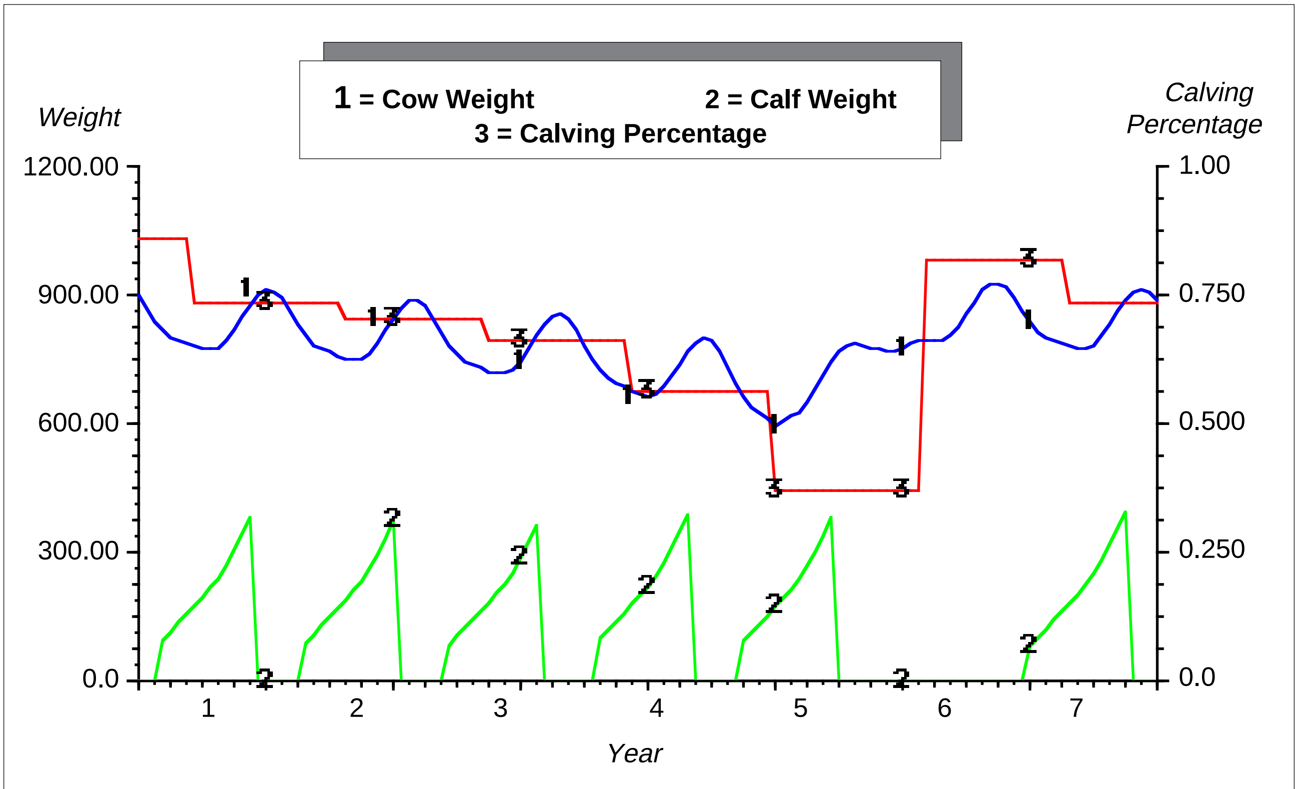

Figure 7

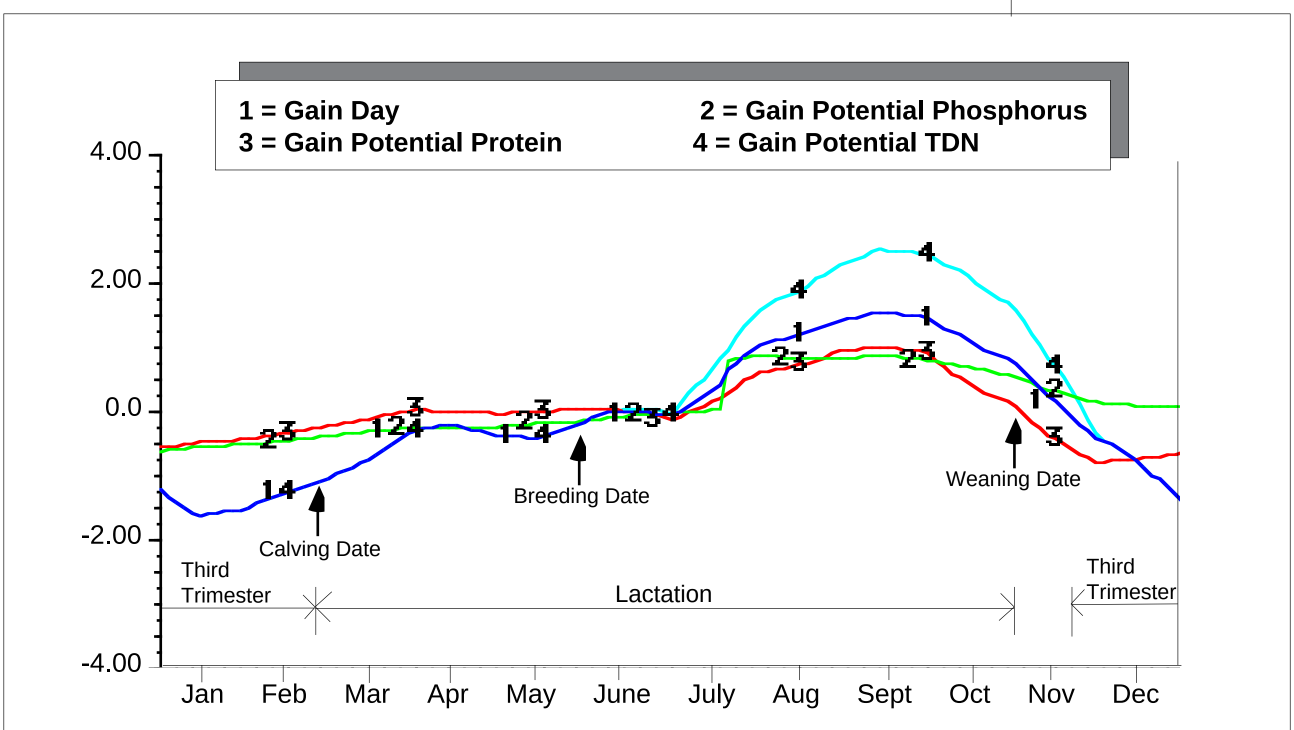

Figure 8

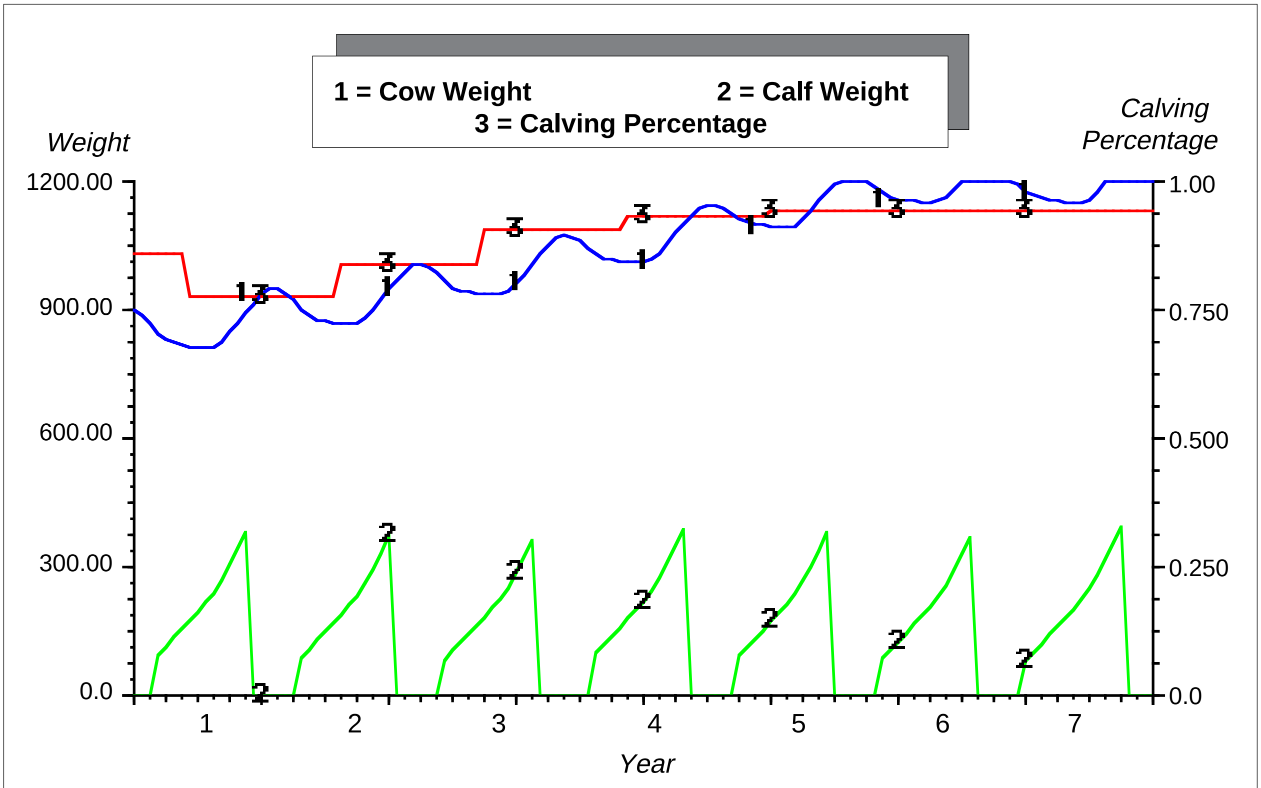

Figure 9

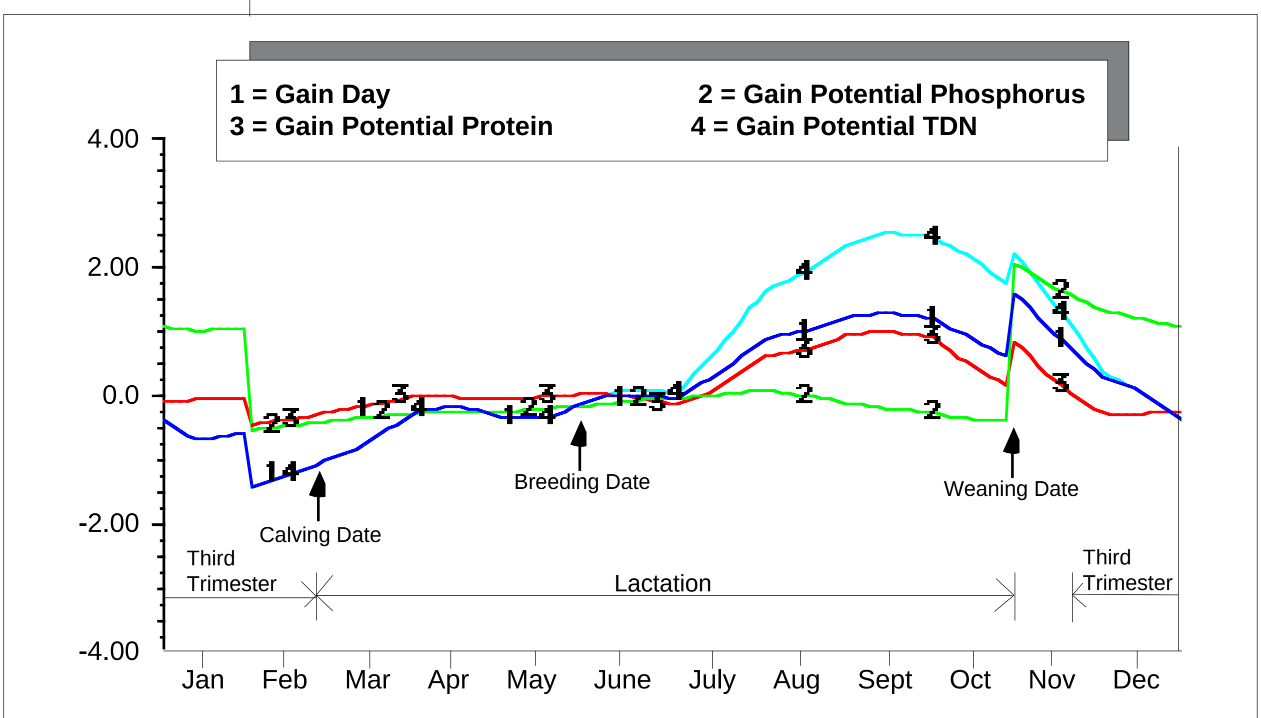

Figure 10

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RANGE COW NUTRITION IN LATE PREGNANCY

Edward LeViness [1]

The success or failure of a cow-calf operation depends on how well the cow's nutritional requirements are met during the last three months of pregnancy.

In Arizona, the majority of cow-calf producers manage their breeding herds for spring calving and the sale of weaner calves in the fall. This is a traditional practice. It is logical and reflects experience gained from generations of cattle ranching in the southwest.

The practice of spring calving, like nearly everything else in the cow business, creates its own share of management problems. One of these concerns deals with the nutritional requirements of the breeding herd during the winter months.

For the cow that has been bred to calve in February or March, or perhaps even earlier, one of the most critical periods in her yearlong productive cycle is the interval between late December through March. This time represents the 7th, 8th and 9th months of pregnancy or what is often referred to as the third trimester of gestation. Unfortunately, however, this is the season when most forages reach their lowest nutrition. This is particularly true with protein and carbohydrate levels and the problem occurs with both grass and browse.

The graphs illustrate the relative nutritive values of grass and browse species found in the southwest:

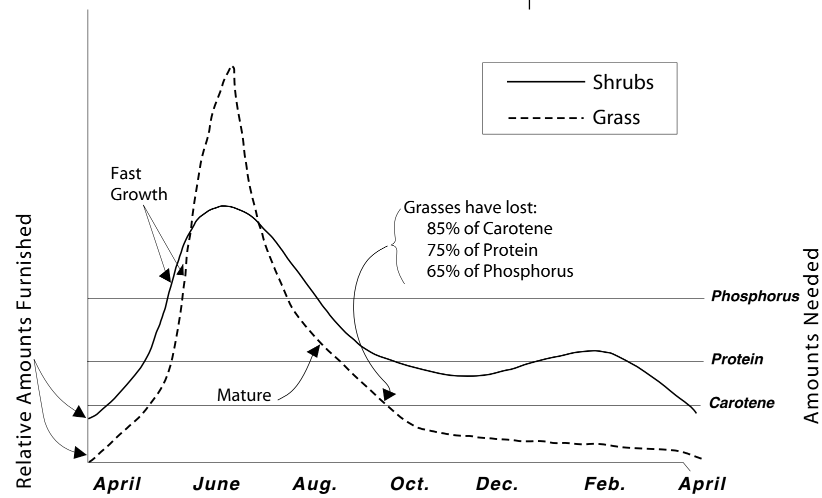

Figure 1. Seasonal Trends in Protein, Phosphorus, and Carotene Content of Range Forage.

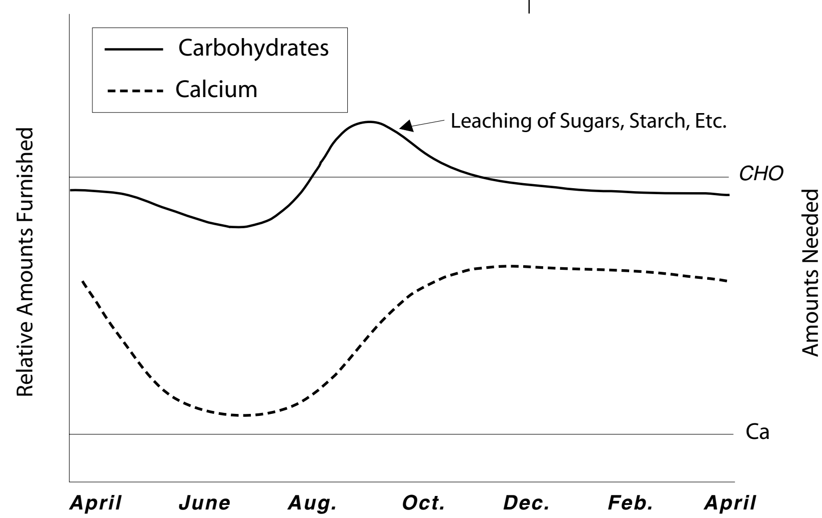

Figure 2. Seasonal Trends in Calcium and Carbohydrates in Range Grass.

It can be seen that grass and browse vary considerably in nutritive levels throughout the year. More important however, from the standpoint of the pregnant cow, is the fact that the nutritive levels of these forages are usually lowest during plant dormancy. This also happens to be a critical time for the cow in the latter stages of pregnancy.

To emphasize the importance of nutrition in the cow and why this 80-90 day period is so vital to her performance, consider a few of the duties expected of the cow that are affected by nutritional intake during this time:

a) she must adequately nourish the developing unborn calf because it triples in weight during the last 3 months of gestation,

b) her thriftiness and body condition must be maintained in order to promote normal calving (weak cows produce weak calves or no calves at all),

c) the cow must insure an adequate supply of milk for the newborn calf,

d) she needs to maintain good health to minimize the interval between calving and first heat after calving,

e) she should stay in good condition to increase the likelihood of conception during the first or second heat period after calving.

With these thoughts in mind, it might be good for the producer whose breeding program is aimed at weaning a marketable calf from as many cows as possible every 365 days, to check the arithmetic involved. The length of gestation in most cows is between 275-290 days. Thus, a beef cow is pregnant for most of the year! So, if the objective is for the cow to calve every 12 months, she has only 75-90 days after calving before she is pregnant again. It is obvious there is little time to waste.

Consider then, the work the cow is expected to complete, the time span she has to work in and the generally inadequate nutritive levels of forages she grazes. It is evident that she will need help.

One logical way to help the animal during this important 80-90 day period is to increase the nutrient level or quality of feed available. It is important to understand this goal. Even under proper grazing management where animal numbers and their daily dry matter requirements are in balance with forage production, there are times when forages will not provide the quality of nutrition necessary to attain the livestock performance level desired.

One of the most common and economical methods of providing the cow with extra nutrition during her critical period is by supplying what the industry refers to as a <u>supplemental feed</u>. The word supplement means something that completes or makes an addition. This is what a supplemental feed is, a nutritional additive that lends balance and helps “round-out” the nutrients provided by range forages.

Supplemental feeds are not designed nor should they be expected to substantially replace dry matter, roughage of range forages or both. (This does not consider true range feed emergencies, wherein the role of supplemental feeds may be altered temporarily.) Most supplemental feeds contain varying quantities of the nutrients protein, carbohydrate, minerals and vitamins.

The questions and details concerning the what, where and when of supplemental feeding represent subjects in themselves and are not dealt with here.

The purpose of this material is to remind stockmen of the vital functions that must take place in the cow during the latter stages of her pregnancy and the part adequate nutrition plays in these functions. It’s up to the rancher to insure that the nutritional needs of the cow during this critical time are met.

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LEAST COST SUPPLEMENTATION

Russell Gum[1]

Supplementation decisions are one of the critical tasks in managing a range cow herd. Should I supplement? When should I supplement? What should I supplement? These are all common and important questions that a rancher must answer. The purpose of this report is to describe a decision aid that can help in answering these questions. A copy of the decision aid in Excel spreadsheet format can be obtained from the author.

The question answered by this decision aid is given:

1) a current weight for a mother cow and a target weight for that cow 12 months in the future

2) expected nutrient analysis for range forages over the year

3) nutrient analyses and costs for possible supplements **what is the least cost supplement plan to insure that the mother cow meets or exceeds her target weight?**

This is an extension of the least cost ration problem described earlier and uses the same basic spreadsheet techniques to solve the problem. The major difference is that instead of constraints on nutrients in the ration we now have constraints on cow weight. To do this we need a way of predicting cow weights. The method used is a modified net energy method. The modifications were to add minerals and protein to the gain formula and to vary the energy requirements as a func-

Figure 1

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1														
2	Month		1	2	3	4	5	6	7	8	9	10	11	12
3	cow weight	lbs	800	790	781	774	773	798	824	835	832	821	811	800
4	pg_energy_req	ratio	1.32	1.6	1.6	1.6	1.6	1.6	1.49	1.38	1.25	0.95	0.95	1.12
5				Calve				Breed						
6	lbs energy	lbs/day	6.00	5.92	5.86	5.82	5.87	6.07	6.23	6.28	6.24	6.16	6.08	6.00
7	pounds_protein	lbs/day	0.75	0.74	0.73	0.73	0.77	0.80	0.80	0.79	0.78	0.77	0.76	0.75
8	pounds minerals	lbs/day	0.00	0.00	0.00	0.01	0.04	0.04	0.03	0.01	0.00	0.00	0.00	0.00
9														
10	net energy for maintenance	lbs/day	6.24	5.76	5.29	4.76	3.61	3.70	4.47	5.32	6.43	6.37	6.30	6.24
11	net energy for gain	lbs/day	-0.24	0.17	0.57	1.06	2.26	2.37	1.76	0.96	-0.19	-0.21	-0.23	-0.24
12														
13	gain-energy	lbs/day	-0.12	0.09	0.31	0.62	1.63	1.66	1.06	0.51	-0.09	-0.10	-0.11	-0.12
14	gain-minerals	lbs/day	-0.99	-1.05	-1.12	-0.89	1.77	2.02	0.46	-0.74	-1.04	-1.02	-1.01	-0.99
15	gain-protein	lbs/day	-0.22	-0.23	-0.23	-0.24	-0.23	-0.27	-0.30	-0.30	-0.25	-0.24	-0.23	-0.22
16														
17	expected gain	lbs/day	-0.35	-0.29	-0.22	-0.06	0.84	0.87	0.36	-0.09	-0.36	-0.36	-0.35	-0.35
18														
19	cost	$/month	2.00	2.00	2.00	2.15	3.15	3.25	2.77	2.25	2.00	2.00	2.00	2.00
20														
21	cost per year	27.56												
22														
23														
24	range forage	lbs consumed	15.00	14.80	14.64	14.52	14.49	14.96	15.45	15.65	15.60	15.40	15.20	15.00
25	hay	lbs fed/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	cottonseed	lbs fed/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	block	lbs fed/day	0.00	0.00	0.00	0.02	0.15	0.17	0.10	0.03	0.00	0.00	0.00	0.00
28	mineral supplement	lbs fed/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

tion of the pregnancy and lactation state of the cow.

Because of the added complexity of this model compared to the simpler ration formulation model, not all spreadsheet solvers will solve this problem. You may have to experiment with the solver option in your spreadsheet to check if it works. The template is available in Excel format and the Excel solver does solve this problem albeit slowly. If you would like current information on what spreadsheets can solve this problem you might consider posting a question to the IRM electronic highway mailing list. (See the Ranchers' Management Guide article on the electronic highway information sources for details on how to do this.)

The basic spreadsheet is displayed in Figures 1 and 2.

How to use the supplement decision guide.

1. Input the starting weight of your cows in cell C3.
2. Input the expected nutrient values and costs for your range forage in rows 30 through 33. This is not a trivial task as the species composition of the diet as well as the nutrient values of the components of the diet vary over the year. However, insight can be gained into the supplement problem by inputting a reasonable estimate of these values based on your experience or perhaps information from extension, blm, forest service or soil conservation service range management professionals.
3. Input the nutrient values and costs for the possible supplements you would like to consider. Commercial supplements have this information on their tags. Values for other feeds such as hay and cottonseed can be obtained for your local extension agent.

Set all of the supplement fed cells (C25:N28) to zero. At this point the

Figure 2

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
29														
30	range forage	% protein	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
31		% energy	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
32		% phosphorus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33		$/au day	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
34														
35	hay	% protein	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
36		% energy	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
37		% phosphorus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38		$/lb	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
39														
40	cottonseed	% protein	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
41		% energy	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
42		% phosphorus	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
43		$/lb	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
44														
45	block	% protein	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
46		% energy	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
47		% phosphorus	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
48		$/lb	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
49														
50	mineral supplement	% protein	0	0	0	0	0	0	0	0	0	0	0	0
51		% energy	0	0	0	0	0	0	0	0	0	0	0	0
52		% phosphorus	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185
53		$/lb	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
54														

spreadsheet will calculate the expected results for the scenario where no supplement is fed. You must analyze this result by inspection and common sense to see if the result is what you would expect to happen if you did not feed any supplement to your cows. If the results are about what your experience and common sense would expect to happen if no supplement were fed then you can proceed to the next step. If not, this problem needs to be fixed before you proceed. The most likely cause for the spreadsheet model and reality to be different is the intake of range forage amount. This value is initially set at 1.875% of the cows weight. This value varies as a function of the quality and availability of forage on your range. If your judgment indicates your cows should not gain as much as the original spreadsheet model indicates for a particular month you need to lower the intake percentage in the appropriate cell. For example if you expect that the November weight gain indicated is too high edit cell M24 and replace the .01875 in the formula with a lower number. The spreadsheet will now recalculate and the new results can be inspected. When you are satisfied that the results reflect what would happen on your ranch you are ready for the next step.

4. Check to see if the December weight meets your target weight. If it does then the problem is solved without any supplement. If not you need to follow the next steps to calculate a least cost supplement plan.

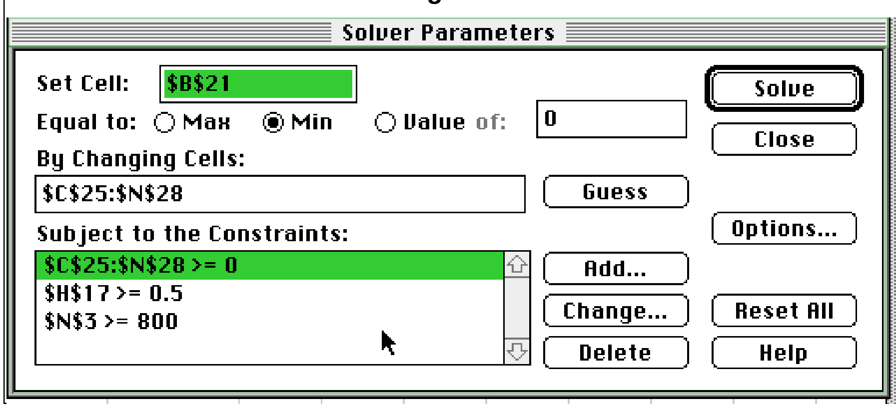
   Choose **Solver** from the formula menu. The following dialog box should appear (Figure 3). If solver does not appear in your menu open the solver add-in the Solver sub-directory of the Macro Library directory.

   Set cell is the cell the solver will attempt to minimize (or maximize depending on which check box is checked) subject to the constraints. In our case B21 is the cell that contains the total feed cost for the cow for the year.

   By changing cells contains all of the things the program can manipulate in its search for an optimum solution. In our case it is the area where the timing and amounts of supplement will be reported. i.e., C25 TO N28.

   Subject to the constraints contains all of the restrictions placed on the solution of the problem. In our case there are three basic constraints. First it is not possible to feed negative amounts of supplement so cells C25 to N27 must be equal to or greater than zero. Second we want to meet the target weight for the cow N3. Finally we want to insure that the cows are gaining at least .5 pounds per day in the period just before and during the breeding season. To do this we constrain H17 to be greater than or equal to .5. If you have a different breeding schedule than the example you will have to adjust this constraint and adjust the pregnancy energy requirements (row 4).

Figure 3



After checking to be sure the set cell, by changing cells and subject to constraints settings are correct click on the solve button. It will take a while for the problem to solve. In fact, it may indicate you have reached the time limit. If this happens just click on continue and let it run a few more minutes. When it finishes click on the option to display the results on the original spreadsheet. Now you should save the results and then analyze what the computer suggested as a supplement plan. Below is the recommendations from the sample problem. The optimal results are displayed in Figure 1, rows 25, 26, 27, and 28.

The computer's suggestions meet all of the constraints, and are the least cost manner of doing so. But you will probably want to use a bit of common sense to modify the computers suggestions. For example, the sample results suggest feeding .02 pounds of block per day per cow in April (cell F27 - Figure 1). Common sense would suggest that this would be more trouble than it was worth. One practical solution would be to feed .17 pounds of block per day per cow in May and none in April instead of the recommended amounts. If you enter this into the spreadsheet you can check to see that you still meet constraints. Other minor modifications in the computer's recommendations may slightly raise costs or cause the constraints to be not quite met. By putting these practical modifications into the spreadsheet and observing their impact on costs and constraints a practical supplement plan can be generated.

SUMMARY

The supplement recommendation spreadsheet can produce useful information to help you develop a sound supplement plan. The computer model is only a tool to help you think about supplement management. It is not an exact answer to be followed no matter what. The functional relationships between nutritional intake and gain are statistically derived approximations. The nutritional values for your range forage will be subject to weather and other random influences. The intake of range forage is an approximation. However, even with the uncertainties involved in the model it can serve as a reasonable starting point for your supplement decisions As with any other ranching decision monitoring is necessary. If you happen to get great weather and the grass is much taller and greener on your range than it was depicted in the spreadsheet you will need to reevaluate your supplement planning. The spreadsheet model can, and should be used throughout the year. Adjustments to the intake function and the nutritional values of the range forage can be made to reflect actual conditions. The model can then be run allowing the remaining months supplement plan to vary to provide information on possible revisions in your supplement plan. To do this you would need to change the **By changing cells** selection under the Solver menu.

While it will take effort to set up the model and get it initially running it will get easier with time. As you use the model and develop information on the nutritional values obtained by your cows from the range forage on your ranch you will be able to fine tune it to your specific ranching conditions.

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FROM:

Arizona Ranchers' Management Guide
Russell Gum, George Ruyle, and Richard Rice, Editors.
Arizona Cooperative Extension

HOW DO DOMESTIC UNGULATES SELECT NUTRITIOUS DIETS ON RANGELANDS?

Larry D. Howery[1], Frederick D. Provenza[2], and George B. Ruyle[3]

INTRODUCTION

Animal learning has been shown to play a major role in the development of diet selection by domestic ungulates. Dr. Frederick Provenza and his associates at Utah State University have conducted a series of experiments over the past 15 years to learn how physiological and behavioral mechanisms govern diet selection. In this paper, we synthesize several key diet selection concepts presented in 4 recent articles (i.e., Provenza et al. 1992; Provenza 1995, 1996, 1997).

PALATABILITY AND PREFERENCE

Palatability is traditionally defined as "the relish an animal shows for a particular plant as forage…which varies with succulence, fiber content, nutrient and chemical content, and morphological features such as spines and thorns" (see Frost and Ruyle, this Guide). Because palatability is defined in terms of plant attributes, it is often called a "plant characteristic." ***Preference*** is traditionally defined as "relative consumption of one plant over another by a specific class of animal when given free choice at a particular time and place" (Frost and Ruyle, this Guide). Because preference is defined in terms of free choice by an animal, it is often called an "animal characteristic." Collectively, these two definitions evoke range animals' well-documented ability to somehow assess the nutritional value of range forages (i.e., palatability), and invariably select a more nutritious diet than is available on average within their particular environment (i.e., preference). In

GLOSSARY OF TERMS

Affective Processes – Involuntary processes that do not require conscious thought. For example, breathing, digestion, and hedonic shifts are affective (involuntary) processes that occur even while an animal sleeps or is anesthetized. *See cognitive processes and hedonic shift.*

Cognitive Processes – Voluntary processes that require conscious thought. For example, walking, running, or seeking/selecting a particular food are cognitive (voluntary) processes. *See affective processes.*

Emetic System – System responsible for nausea, vomiting, and malaise in animals. It is a critical component of the affective (involuntary) system and plays a key role in the formation of conditioned taste aversions to forages that cause malaise. *See affective processes, malaise.*

Hedonic Shift – A shift in preference (i.e., either increased or decreased intake) for a food following positive or negative postingestive feedback. *See affective processes and postingestive feedback.*

Malaise – Negative postingestive feedback. Feeling of malaise (i.e., nausea or unpleasant feelings of physical discomfort) after ingesting a food or foods. *See postingestive feedback, satiety.*

Postingestive feedback (PIF) – Feedback from the gut to the brain that allows animals to sense the nutritional or toxicological effects of food ingestion (positive or negative) and accordingly adjust their preference (increase or decrease intake) for the food. *See hedonic shift, malaise, satiety.*

Satiety – Positive postingestive feedback. Feeling of satisfaction after ingesting a food or foods. *See malaise, postingestive feedback.*

addition to selecting nutritious diets, range animals generally avoid plants that cause toxicosis, inhibit digestion, or cause malnutrition. This is remarkable given that nutrients, toxins, and digestion inhibitors vary seasonally and by location, both among and within plant species. Animals do occasionally over-ingest plant nutrients and toxins (discussed later), but generally speaking, range herbivores commonly select forages that meet their nutritional needs and avoid forages that do not. Although this observation has been often reported in the literature, Dr. Provenza's research is the first to offer both theoretical and experimental evidence that explains how this important process occurs. His work suggests that animal preference for foods (and hence their palatability) are best understood as the interrelationship between a food's taste and its postingestive effects, which is determined by a food's chemical (and physical) characteristics, and by an animal's age, morphology, and physiological condition.

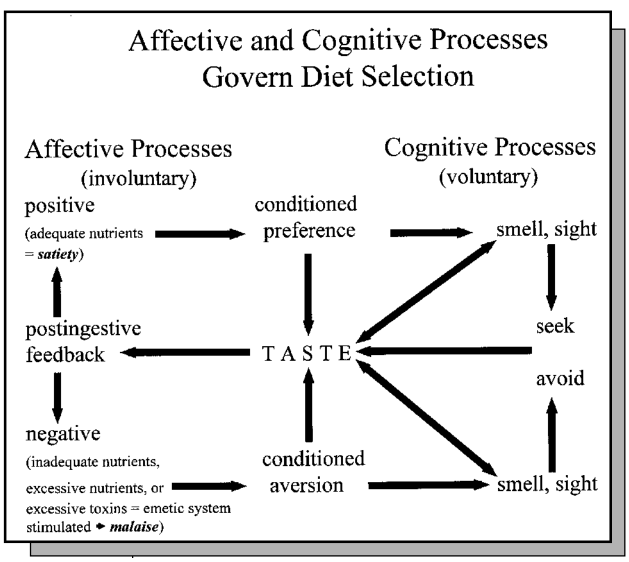

Figure 1. Schematic representation of affective and cognitive processes in diet selection. The affective system links the taste of food with its postingestive feedback (PIF). The cognitive system integrates the senses of taste, smell, and sight which animals use to seek or avoid foods in accord with positive or negative PIF. There is an iterative exchange of information between these systems which allows animals to modify their foraging behavior in response to changing environmental conditions, and in response to changing nutritional needs (adpated from Provenza et al., 1992).[4]

POSTINGESTIVE FEEDBACK (PIF) AND HEDONIC SHIFTS

Animals regulate their intake of forages according to whether ***postingestive feedback (PIF)*** that results from forage ingestion is positive or negative. Animals change their "preference" for various forages (i.e., forages become more or less "palatable" and relatively more or less "preferred") in accord with PIF. This process is know as a ***hedonic shift***. For example:

- Lambs develop strong preferences even for poorly nutritious foods such as straw (i.e., increased intake, a positive hedonic shift) when it is eaten during stomach tubings of energy (starch or glucose) or nitrogen (urea, casein, gluten).
- Conversely, lambs quickly learn to avoid a previously palatable food (i.e., decreased intake, a negative hedonic shift) after receiving one dose of lithium chloride (LiCl), a compound that causes nausea.

These results demonstrate that palatability and preference can be manipulated experimentally. However, palatability and preference are also altered in nature when chemical composition of rangeland plants (i.e., forage quality) changes across space (e.g., range sites differing in kind and amount of available forage) and time (e.g., decline in forage quality as plants mature).

AFFECTIVE AND COGNITIVE SYSTEMS

Two interrelated systems mediate hedonic shifts via PIF from the gut to the brain: ***affective systems*** and ***cognitive systems***. Affective involuntary processes are mediated subconsciously; cognitive processes are mediated consciously. The senses of taste, smell, and sight are linked with PIF across the two systems, but are functionally different (Figure 1). We will discuss affective and cognitive systems (and their affiliated senses) separately in order to highlight their primary functions, but this does not mean they operate independently of one another. Animals readily exchange information between these two systems through their senses of taste, smell, and sight.

Affective (involuntary) processes allow animals to associate the taste of forages with their positive or negative PIF and respectively form either conditioned preferences or conditioned aversions. If a forage causes malaise (i.e., nausea), animals acquire conditioned taste aversions (mild to strong). Malaise may occur when the forage ingested contains excess nutrients (e.g., energy, protein, minerals), excess toxins (e.g., tannins, alkaloids), or inadequate nutrients (Figure 2). What constitutes excesses and deficits in nutrients or toxins depends on the animal's age, morphology (e.g., small vs. large animal, ruminant vs. cecal digestive system), and physiological condition (Figure 3). On the other hand, if a forage causes satiety (the sensation of being satisfied to the full), animals acquire conditioned taste preferences (mild to strong). Satiety results when an animal ingests the kinds and amounts of forages necessary to meet its nutritional requirements, again depending on age, morphology, and physiology.

Cognitive (voluntary) processes allow animals to integrate the senses of taste, smell, and sight to discriminate among forages and make "conscious" choices (i.e., behavioral modification) to select or avoid a food based on previous experience with the food's PIF (Figure 1). If a food previously resulted in malaise (i.e., negative PIF), its taste becomes undesirable and the animal uses its senses of smell and sight to

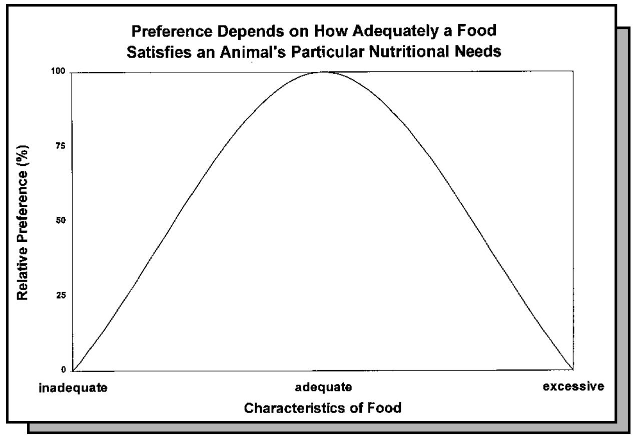

Figure 2. Preference is dependent on how adequately a food satisfies an animal's particular nutritional requirements. Preference resides along a continuum, wherein foods with low or excessive concentrations of nutrients (or excessive concentrations of toxins) cause preference to decline, and foods with adequate amounts of nutrients cause preference to increase (adapted from Provenza 1995).[4]

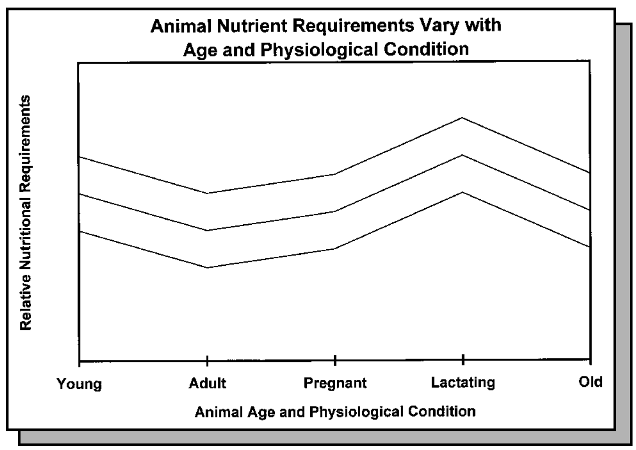

Figure 3. Animal nutrient requirements vary with age and physiological condition. The ideal nutritional state (center line) occurs when all nutrients are obtained simultaneously. It is dynamic and multidimensional, with as many dimensions as there are functionally relevant nutrients. However, animals need not maximize (optimize) intake of any particular nutrient or mix of nutrients within each meal or even on a daily basis, because they can withstand departures from the normal average intake of nutrients (i.e., energy-rich substances, nitrogen, various minerals, and vitamins). Rather, homeostatic regulation needs only some increasing tendency, as a result of a gradually worsening deficit of some nutrient (lower line) or of an excess of toxins or nutrients (upper line), to generate conditions (i.e., malaise) to correct the disorder (i.e., cause the animals to change food selection). Malaise causes animals to increase diet breadth, to acquire preferences for foods that rectify states of malaise, and to exhibit state-dependent food selection (adapted from Provenza 1995).[4]

avoid the forage in the future; the converse would occur if a food previously resulted in satiation (i.e., positive PIF).

To summarize, animals use the affective system to evaluate the postingestive consequences of ingesting a forage, and the cognitive system to modify their foraging behavior according to whether PIF was positive or negative. Although animals integrate the senses of taste, smell, and sight to seek or avoid foods that have respectively caused positive or negative PIF, taste is most strongly linked with PIF. Animals first relate the taste of a food with its PIF through the affective (involuntary) system before smell and sight become functional in the cognitive (voluntary) system (Figure 1). Hence, foraging behavior entails a never-ending exchange of information systems whereby animals sample forages, associate positive or negative PIF from the digestive tract with a forage's taste, integrate forage taste with smell and sight, and then seek or avoid forages accordingly. Together, these two systems give animals flexibility to learn and modify their foraging behavior in response to changing environmental conditions (e.g., variation in plant nutrients and toxins across space and time), and in response to changing nutritional needs (old vs. young, lactating vs. non-lactating, etc.).

CONDITIONED TASTE AVERSIONS

Conditioned taste aversions have evolved as a survival mechanism to help animals limit their intake of otherwise nutritious plants that contain toxins, or plants that fail to meet nutritional requirements. Supporting this notion is the fact that conditioned taste aversions have been demonstrated in many different animal species (e.g., snakes and tiger salamanders; quail, blackbirds, blue jays, and crows; rats, opossums, and mongooses; coyotes and timber wolves; goats, sheep, and cattle; olive baboons and humans) using a variety of compounds. The ***emetic system*** is a critical component of the affective system (see previous section), and plays a key role in the formation of conditioned taste aversions to forages that cause malaise. The emetic system mediates interactions between the brain and the digestive tract and is the same system responsible for nausea and vomiting in humans.

Because the emetic system is a subset of the affective system, it involves non-cognitive or involuntary processes. Accordingly, aversive PIF may occur even as an animal sleeps, is anesthetized, or with short (i.e., less than 1 hour) or long delays (i.e., up to 12 hours) between food ingestion and PIF. This is critical because digestion and absorption rates (i.e., PIF) vary from fast to slow depending on animal species and forage characteristics. Although conditioned taste aversions (and preferences, discussed next section) are non-cognitive, this information is clearly integrated with the cognitive system through the senses of sight and smell. After animals relate a forage's taste with negative PIF (malaise), smell and sight become powerful predictors of anticipated negative PIF and the cognitive response is to avoid the forage when encountered in the future (Figure 1). The emetic system may be stimulated (resulting in malaise and conditioned taste aversions) when animals ingest forages containing excess nutrients or toxins. There is also limited evidence that the emetic system may be stimulated when forages ingested contain inadequate nutrients (Figure 2). Some experimental and anecdotal examples of conditioned taste aversions follow.

EXCESS NUTRIENTS

- Ruminants prefer high-energy foods like grains, but limit grain intake and increase intake of alternative foods once grain is over-ingested, evidently because negative PIF caused by excess by-products from microbial fermentation (i.e., volatile fatty acids such as lactate, acetate, and propionate) produces a negative hedonic shift within a meal.

- Sheep given a high dose of propionate during a meal (i.e., high energy) acquire a persistent aversion to the food.

- Ruminants eating foods high in rumen-degradable protein (through microbial fermentation) experience toxic levels of ruminal ammonia which cause declines in intake.

- Goats learn to limit intake of various sources of non-protein nitrogen within minutes of ingestion. For instance, urea is quickly converted into ammonia, which explains why intake rapidly declines as urea is added to foods.

- Sheep fed an oat hay-lupine mixture containing either 0, 1.7, 3.3, 6.3, 12, or 21% of a mineral mix ate less as the mineral concentration was increased. Most of the sheep consuming the highest mineral concentrations eventually refused to eat the food.

EXCESS TOXINS

- Goats prefer old-growth to current-season growth blackbrush *(Coleogyne ramosissima*) twigs, even though current-season growth contains more nitrogen (2.3 vs. 1.7%) and is more digestible (48 vs. 38%) than old-growth. This is because current-season growth contains a condensed tannin that causes aversive PIF.

- Toxic compounds in larkspur (*Delphinium barbeyi*) and tall fescue (*Festuca arundinacea*) (alkaloids), brassica crops (glucosinolates), and sacahuista (*Nolina microcarpa*) (saponins, coumarins, furocoumarins, and anthraquinones) cause decreased intake in cattle, sheep, and goats.

- Various toxic compounds in leafy spurge (*Euphorbia esula*), bitterweed (*Hymenoxys odorata*), poor quality silage, and sagebrush (*Artemisia* spp.) contain compounds that decrease intake in range herbivores.

- Sheep quickly acquire aversions to foods containing the toxin lithium chloride (LiCl).

INADEQUATE NUTRIENTS

- Deficits or imbalances of energy, nitrogen, and amino acids cause lambs and rats to decrease intake.

- Phosphorus deficient diets cause cattle, sheep, and goats to decrease intake; the decline in intake is directly related to the degree of the deficit.

CONDITIONED TASTE PREFERENCES

Conditioned taste preferences, like conditioned taste aversions, are mediated through the affective and cognitive systems, except of course, the cognitive response of animals is to seek forages that have previously caused positive PIF (Figure 1). Animals may form preferences and seek forages when their taste has been paired with adequate: 1) energy, 2) nitrogen, or 3) recovery from nutritional deficiencies or malaise. Some experimental and anecdotal examples of conditioned taste preferences follow.

ENERGY AND PROTEIN

- Lambs acquire strong preferences for non-nutritive foods (e.g., straw or grape pomace) or flavors (e.g., maple, apple, coconut, onion) paired with energy sources (e.g., starch or glucose) or with volatile fatty acids (e.g., propionate or acetate) that are energy sources.

- Lambs also acquire strong preferences for flavored straw paired with protein (e.g., casein, gluten) or non-protein (e.g., urea) sources of nitrogen.

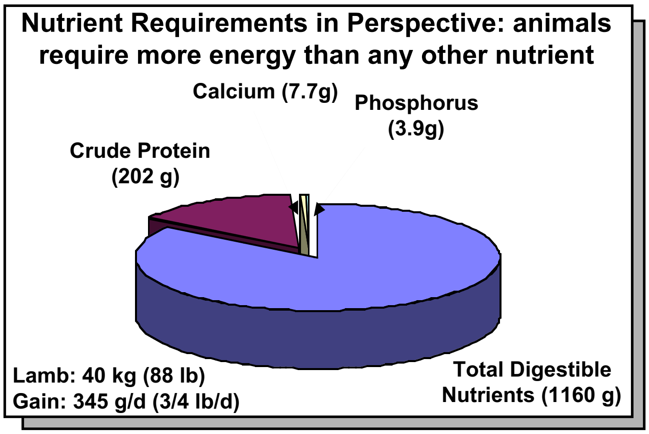

Figure 4. Animals require more energy daily than any other nutrient. For example, a 40 kg lamb requires 1160 g of total digestible nutrients (TDN), but only 202 g of crude protein (CP), 7.7 g of calcium (Ca), and 3.9 g of phosphorus (P) to gain 345 g/d (3/4 lb/d) (NRC 1985).

Meal to Meal Preference for Energy and Protein Depends on Whether Energy and Protein Requirements Were Satisfied during Previous Meals

	Preference for:				
Animal previously consumed:	energy		protein		water
water	energy	>	protein	>	water
energy	↓		↑		no change
protein	↑		↓		no change

Figure 5. Animals typically acquire stronger preferences for non-nutritive foods paired with energy than with protein. However, meal to meal preference for energy and protein depends on whether energy and protein requirements were satisfied during previous meals. After a high-energy meal, lamb preference for energy declines and preference for protein increases; the converse is also true.

- Lambs acquire the strongest preferences when the sources of energy and nitrogen ferment at similar rates and in similar amounts in the rumen. Conversely, when the balance of energy and protein is skewed in rate or amount, animals tend to form aversions to the food.

- Energy and protein can both readily change preferences, but animals require much more energy than protein each day (Figure 4). Accordingly, animals typically acquire stronger preferences for non-nutritive foods paired with energy than with protein. However, meal to meal preference for energy and protein depends on whether energy and protein requirements were satisfied during previous meals. After a high-energy meal, lamb preference for energy declines and preference for protein increases; the converse is also true (Figure 5).

RECOVERY FROM NUTRITIONAL DEFICIENCIES

- Lambs suffering from acidosis (excess energy) drink more of a sodium bicarbonate solution; lambs not suffering from acidosis prefer plain water.

- Cattle readily consume supplemental protein blocks when ingesting forages low in protein.

- When browsing a low-protein blackbrush diet (1.5% nitrogen), goats consume woodrat houses soaked in urine (nitrogen).

- Sheep increase intake of a protein-deficient diet following infusions of protein into the duodenum.

- Rats prefer flavors associated with their recovery from threonine (an amino acid) deficiency.

- Sheep apparently rectify mineral deficits (e.g., P, S, and Se) by ingesting mineral supplements; cattle consume non-food items, apparently to rectify P deficiencies. Deer and other ungulates experiencing mineral deficits eat antlers. Bighorn sheep that use rodent middens as mineral licks may do so to rectify nutrient deficiencies.

- Cattle ingesting mineral deficient forages lick urine patches of rabbits and man, chew wood, consume soil, eat fecal pellets of rabbits, and ingest non-food items such as plastic, feathers, bones, cinders, sacks, and tins. Mineral deficient cattle also eat rabbit flesh and bones, whereas non-deficient animals may sniff or lick the flesh, but never eat it, and they ignore the bones.

- Other ruminants experiencing various nutrient deficiencies have been known to eat the following: live and dead lemmings, rabbits, birds (caribou, red deer, sheep), ptarmigan eggs (caribou), arctic terns (sheep), and fish (white-tailed deer).

SAMPLING FAMILIAR VS. NOVEL FORAGES

Animals may frequently change intake of familiar foods in familiar environments because the nutrient and toxin content of familiar plants can change dramatically within a matter of hours or even minutes depending on previous herbivory and/or environmental conditions. If toxicity decreases (or nutrient content increases), the food is no longer paired with negative PIF and intake may increase. Conversely, forage intake may decrease as forage toxicity increases or as nutrient content decreases. Thus, forage sampling and PIF provide animals with a means of tracking and adapting to changes in nutrients and toxins in familiar foraging environments.

Animals sample new (novel) forages even more cautiously than familiar forages evidently because the postingestive consequence of ingesting a new forage is unknown. Animals are apt to “blame” a novel food for negative PIF even when it is not responsible for the malaise. For instance, young animals that were given LiCl (i.e., negative PIF) avoided a novel food when fed a combination of one nutritious-novel and four nutritious-familiar foods even though one of the familiar foods actually contained the LiCl. “Blaming” novel rather than familiar forages for aversive postingestive consequences likely evolved as a means of protecting herbivores from over-ingesting potentially harmful new foods before confirming their PIF (i.e., positive or negative) by careful sampling as described above.

Thus, range herbivores routinely sample both nutritious and toxic forages (both familiar and novel) and regulate forage intake according to whether PIF is positive or negative. In addition to sampling and PIF, different animal species have evolved specialized physiological mechanisms that bind, metabolize, or detoxify certain thresholds of harmful plant compounds. However, the capacity of these mechanisms is seldom exceeded because animals quickly acquire taste aversions and limit intake before toxicosis ensues. Physiological mechanisms work in concert with PIF, and provide animals flexibility to regulate their intake and ingest adequate diets in ever-changing foraging environments. This is impressive considering the millions of bites that range herbivores take each day across rangelands that contain a diverse array of nutritious and harmful plant compounds.

WHY DO ANIMALS SOMETIMES OVERINGEST NUTRIENTS AND/OR TOXINS?

Animals occasionally over-ingest plant nutrients and toxins that may cause declines in intake, production, and even death. This probably occurs whenever an animal fails to properly relate the taste or smell of a particular forage with its PIF, and the animal's physiological means for binding, metabolizing, or detoxifying toxic compounds is exceeded. Any of the following scenarios (or combinations thereof) involving both the affective and cognitive systems could be responsible for such a breakdown.

EMETIC SYSTEM NOT STIMULATED

The emetic system apparently must be stimulated (i.e., malaise must be experienced by animals) to produce a conditioned taste aversion. However, over-ingestion of certain nutrients and toxins may not stimulate the emetic system.

- Animals that over-ingest alfalfa experience bloat and decrease short-term intake, apparently because tension receptors in the rumen and reticulum are stimulated which may cause short-term physical discomfort. However, bloat apparently does not stimulate the emetic system or cause a long-term negative hedonic shift because animals will ingest alfalfa soon after bloat subsides. In contrast, forages that stimulate the emetic system (cause malaise) have been avoided for at least 3 years.
- Some toxic compounds (e.g., tannins) stimulate the emetic system and cause conditioned taste aversions. Other compounds (e.g., gallamine, naloxone) may not stimulate the emetic system but instead cause aversions to physical locations or other external stimuli.

INTERACTIONS BETWEEN AVERSIVE AND POSITIVE PIF

Animals are more likely to be poisoned when PIF from a toxin is not experienced for more than 12 hours. Beyond 12 hours, animals may not be able to distinguish which foods cause positive or negative PIF. The longer the delay between food ingestion and aversive feedback, and the higher proportion of positive to negative PIF during that time, the more likely it is that livestock will continue to ingest the food.

- Some animals may die from over-ingesting larkspur *(D. barbeyi)* because there is immediate positive PIF but delayed aversive PIF. For instance, cattle ingest larkspur because it initially enhances ruminal fermentation and digestion (i.e., it is high in energy and protein). Consumption generally increases over a 2 to 4 day period before declining dramatically when alkaloids have their maximum aversive effects. A somewhat similar scenario may occur when animals over-ingest alfalfa and become bloated. Positive PIF from nutrients may cause a strong liking for a nutritious food like alfalfa (i.e., a positive hedonic shift) that overrides any short-term physical discomfort (i.e., stimulation of tension receptors in the rumen and reticulum) due to bloat.
- Poisoning is delayed when animals consume various locoweed species *(Astragalus* and *Oxytropis spp.)* that contain indolizidine alkaloids. Cellular damage does not occur for 8 days and there are no clinical signs of poisoning for 3 weeks. Animals acquire aversions to such foods only after vital organs (e.g., the liver) have been damaged.

- Liver damage caused by pyrrolozidine alkaloids in species such as groundsel *(Senecio* spp.) is progressive and death may not occur for months or even years.

DIFFERENTIATING NUTRITIOUS FROM TOXIC PLANTS IN UNFAMILIAR ENVIRONMENTS

It is probably more difficult for herbivores to differentiate nutritious from toxic foods in unfamiliar environments because all foods may be novel.

- Ninety percent of naïve goats introduced into pastures containing white snakeroot *(Eupatorium rugosum)* died during the first 2 weeks of grazing. Survivors apparently learned to avoid the plant.

- Sheep in South Africa eat groundsel for the first 3 days in an unfamiliar pasture but then refuse to eat the plant even if starving.

- Cattle ranchers in South Africa stomach-tube a sublethal preparation of tulips *(Homeria pallida)* to prevent deaths, and report that only naïve or extremely hungry animals eat the plant. Naïve animals given the preparation, or untreated animals that survive beyond 4 days of grazing pastures containing the plant learn to avoid tulips.

- Many cattle deaths caused by larkspur *(D. barbeyi)* occur within 10 to 14 days after cattle enter a new pasture. Survivors may learn to avoid ingesting a lethal dose.

- When foraging in a familiar environment, sheep ate less of a familiar-aversive food than in an unfamiliar environment. Conversely, when foraging in an unfamiliar environment, sheep ate less of a novel-harmless food than when in a familiar environment. These results suggest that animals generally perform better when foraging on familiar foods in familiar environments.

CHANGES IN ENVIRONMENTAL CONTEXT MAY ALTER ANIMAL PHYSIOLOGY

Even when familiar plants are available in unfamiliar environments, changes in an animal's environmental context may render its physiological mechanisms (e.g., binding, metabolizing, and detoxifying) less effective and cause animals to be more susceptible to toxicosis. In this case, the same dose of a familiar toxin may be more harmful in an unfamiliar than in a familiar environment. Work in this area has mainly involved drug research on humans and rats, but there are important implications concerning how range animals may respond to familiar toxic plants after being moved to an unfamiliar environment.

- A cancer patient died when injected with morphine in a different room; the patient had tolerated the same dose when injected every 6 hours for 4 weeks in a familiar room.

- Social drinkers become more impaired when they drink at unusual times or in different settings.

- Rats with or without previous experience with heroin were given a strong dose either in a familiar or a unfamiliar environment. The dose was lethal for:

  - **32%** of the **experienced** rats in a **familiar** environment.

  - **64%** of the **experienced** rats in an **unfamiliar** environment.

  - **96%** of the **inexperienced** rats in an **unfamiliar** environment.

- Cows raised in Gila county Arizona and moved 100 miles east to Apache county suffered severe lupine and locoweed poisoning. Sister cows that remained in Gila county did not experience lupine or locoweed poisoning even though these species were available in small to moderate stands.

SOCIAL FACILITATION

Animals can also influence what one another eat.

- A group of heifers that were averted to larkspur (with LiCl) avoided the plant over a 3-year period until they were placed in a pasture with nonaverted heifers, at which point they began eating larkspur at similar levels to the nonaverted heifers.

SUBTLE MOLECULAR CHANGES INCREASE PLANT TOXICITY

Animals may be unable to readily detect subtle molecular changes that increase plant toxicity.

- Lambs were unable to detect that LiCl had been added to a previously "safe" familiar food (barley) when it was fed in combination with a novel food (milo). The lambs instead avoided milo and continued to eat the familiar barley, even though barley actually contained the toxin.

- Cattle typically increase intake of larkspur *(D. barbeyi)* after a drop in barometric pressure and mortality increases, probably because changes in plant chemistry simultaneously increase both the palatability *and* toxicity of the plant. Such changes likely increase susceptibility to poisoning.

- Bitterbrush *(Purshia tridentata)* is more palatable than blackbrush both for goats and snowshoe hares, even though both shrubs contain condensed tannins. Slight chemical differences render condensed tannins in blackbrush more aversive to herbivores.

TOXINS IN MORE THAN ONE PLANT

It may be difficult for herbivores to associate toxicity with a specific food when the same toxin exists in more than one food, or when two or more compounds in different foods interact to cause toxicity.

- Goats and deer ingest many different browse species that are high in tannins. It may be difficult for them to distinguish PIF among several different plant species that contain the same (or nearly the same) compound.

- Sheep that consume hemlock (*Cicuta spp.)* may then be more susceptible to compounds in crown beard *(Verbesina enceliodes)*.

- Sheep that consume black sagebrush *(Artemesia nova)* before horsebrush *(Tetradymia glabrata)* are predisposed to photosensitization. Photosensitization by itself is not likely to cause a food aversion because the emetic system is not directly stimulated, but liver dysfunction associated with ingesting these two plant species might indirectly stimulate the emetic system and ultimately cause a conditioned food aversion.

- Various locoweed species contain toxic nitrogen compounds and selenium, which when combined increases their toxicity.

SUMMARY

Animals continually sample and evaluate the nutritional value (i.e., PIF) of forages using their senses of taste, smell, and sight. Postingestive feedback adjusts a forage's hedonic value (i.e., preference and palatability) commensurate with its utility to the animal (i.e., animal age, morphology, and physiology) enabling survival when both the animal's foraging environment and nutritional needs are constantly changing. Plant species that cause positive hedonic shifts are usually highly correlated with nutritional well-being, while plant species that cause negative hedonic shifts are typically highly correlated with nutrient deficiencies and toxicosis. Hence, what makes a forage taste "good or bad" (and thus, sought or avoided) is not taste *per se*, but rather nutritional benefits or deficits received from forage ingestion, which are sensed by animals through PIF and linked with a forage's taste. Animals integrate and use their senses of taste, smell, and sight to seek foods that cause positive PIF (i.e., nutritional well-being) and avoid foods that cause negative PIF (i.e., nutrient deficiencies and toxicosis), and can thus be described as possessing a high degree of "nutritional wisdom." This process occasionally breaks down when animals fail to properly link the PIF of a particular food with its taste, smell, or sight, and their physiological means for binding, metabolizing, or detoxifying toxic compounds is exceeded.

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[4]*Figures 1-3 were originally published in similar form in the Journal of Range Management. They are reproduced here by permission of the Journal.*

FROM:

Arizona Ranchers' Management Guide
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Arizona Cooperative Extension

MATCHING FORAGE RESOURCES WITH COW HERD SUPPLEMENTATION

Jim Sprinkle[1]

INTRODUCTION

In any supplementation program, it is essential that forage resources be stocked such that there is adequate forage quantity available per animal unit. If forage quantity is insufficient, then the supplementation program will be ineffective. The object of supplementation programs (usually protein supplements) is to make-up deficiencies in forage quality to increase passage rate of forage and thus increase forage intake of the cow.

Forage intake of the cow declines with decreased forage quality. Cellulose content in mature forage increases and requires increased rumen residence time for rumen microbes to break down chemical bonds. Also, protein content of mature forage decreases, allowing less protein to be available for making new rumen microbes. The net effect is for the passage rate of forage and forage intake to decline (Table 1).

A general rule is for daily protein supplementation to be limited to around 2 lbs. a day in order to avoid forage substitution effects. If energy supplements are fed, then it is generally expected that negative forage substitution effects will occur.

COW NUTRITIONAL REQUIREMENTS

An animal unit day (AUD) is defined as 26 lbs. of forage per day for a 1000 lb. cow and her calf. If the forage is not green and actively growing, protein, phosphorus, and sometimes energy content of the forage may be deficient. In order to meet the dietary protein requirements of the cow herd, the forage needs to contain 7% protein or 1.6 lbs. per day for a nonlactating and 9.6% or 2.0 lbs. per day for a 1000 lb. lactating cow milking 10 lbs. a day. Calcium and phosphorus requirements for a nonlactating 1000 lb. cow in the last trimester of pregnancy are .26% calcium or .81 oz. per day and .20% phosphorus or .63 oz. per day. For a lactating 1000 lb. cow, .28% calcium or .88 oz. per day and .22% phosphorus or .70 oz. per day are required.

As mentioned above, protein requirements increase with lactation. For early lactation (18 lbs. of milk), protein requirements are 2.14 to 2.24 lbs for a 1000 lb. cow. For late lactation (7 lbs. of milk), protein requirements are 1.8 to 1.9 lbs. for a 1000 lb. cow. Protein requirements are lowest for non-lactating cattle during mid-pregnancy, or only 1.4 lbs.

Table 1. Forage Intake of Lactating Cattle at Different Forage Digestibilities[a]

Forage Digestibility or TDN %	Amount Required to Eat to Meet Maintenance Requirements, % of Body Weight[b]	Amount Can Eat at the Forage Digestibility Listed, % of Body Weight[c]
43	3.2	1.2 to 1.3
45	3.1	1.7 to 2.0
50	2.8	1.9 to 2.1
55	2.6	1.7 to 2.1
58	2.4	1.9 to 2.5
60	2.3	2.0 to 2.5
62	2.3	2.3 to 2.8
64	2.2	2.6 to 3.2
Greater then 64		2.6 to 3.2

[a]For a 1000 lb. cow milking 10 lbs. / day.
[b]The point of intersect for mainintenance requirements and what the animal can eat is around 56% digestibility for lactating animals and about 52% digestibility for nonlactating animals.
[c]Research from various sources including Kronberg et al., 1986. *J. Range Manage.* 39:421; Wagner et al., 1986. *J. Anim. Sci.* 63:1484; Havstad and Doornbos, 1987. Proc. West. Sec. Amer. Soc. Anim Sci. p. 9; Sprinkle, 1992. M.S. Thesis, Montana State University.

Table 2. Maintenance Requirements for Range Cattle

Cow weight, lbs.	Protein required, lbs., nonlactating range cow	Mcal of ME required, nonlactating range cow[a]
800	1.4	15.1
900	1.5	16.5
1000	1.6	18.0
1100	1.6	19.2
1200	1.7	20.5
1300	1.8	21.8
1400	1.9	23.0
1500	2.0	24.2
1600	2.1	25.4
1700	2.2	26.6
1800	2.3	27.8
Additional requirements for milk production: Add to the above maintenance requirements if cow is lactating.		
Estimated lbs. of milk production/day	**Additional lbs. of protein required/day**	**Mcal of ME required for milk**
5	.15	2.4
8	.24	3.8
10 (late lactation; 100 days or more)	.30	4.8
12	.36	5.8
14	.42	6.7
16	.48	7.7
18 (peak lactation; 60 to 70 days; most beef breeds)	.54	8.6
20	.60	9.6
22 (peak lactation; more typical of breeds such as Simmental)	.66	10.6

[a]ME = metabolizable energy; Mcal = megacalories (1,000,000 calories). Increase maintenance requirements by 10% if Charolais, Simmental, or other large framed breed crosses; increase by 15% for dairy crosses; reduce by 10% for Brahman crosses. If daytime temperatures exceed 95˚ F, increase maintenance requirements 25%.

Human energy needs are specified in calories. Human calories are actually equal to 1000 calories, so an average male diet of 3000 calories per day is equal to 3,000,000 calories. Since cattle are much larger than humans, energy needs for cattle are listed in megacalories of metabolizable energy. A megacalorie (Mcal) is equal to 1,000,000 calories. Metabolizable energy (ME) is that amount of energy in feed or forage thatis available to be metabolized or used by the body for maintenance, production, work, and heat regulation. The energy requirement for a 1000 lb. nonlactating cow is 18,000,000 calories or 18 Mcal of ME per day. To maintain a 1000 lb. range cow milking 10 lbs. per day requires approximately 23,000,000 calories or 23 Mcal of ME per day. Energy requirements for cows with greater milk production are increased by .48 Mcal of ME per lb. of milk (1 gallon of milk = 8.62 lbs.). Table 2 lists maintenance requirements for different sizes of cattle.

Energy is used to produce milk with about the same efficiency as energy is used to maintain essential body functions. Energy for body weight gain is used less efficiently than energy for milk production with a greater portion of the metabolizable energy being lost as heat as body tissue is formed. Poor quality forages promote very little body weight gains while the energy density of grain for body weight gain can be up to 7 times greater than that of inferior quality forage. Because of the variability in available energy for body weight gain among different feedstuffs and the accompanying inefficiency of gain, a different system of specifying energy requirements for gain (net energy for gain or NE_g) is recommended by the National Research Council. Net energy for gain or NE_g in a particular feed or forage is always less than ME (see Table 3). Table 3 lists ME and NE_g values for known digestiblities or total digestible nutrients (TDN) of forages or feeds.

The energy costs of NE_g required for body weight gain has been determined by research. Energy costs are dependent upon fat content of the gain, but for most range cows, each 1 lb. of live weight gain requires approximately 2.1 Mcal of NE_g. Live weight gain can only occur after the cow's maintenance and lactation requirements are met. If a 1000 lb. lactating cow milking 10 lbs. per day consumed 24 lbs. of forage with a digestibility of 60%, then 23.5 lbs. of the forage would satisfy her maintenance requirements of 23 Mcal (see calculation below).

23 Mcal ME required per day for maintenance and lactation

$$\div \frac{.98 \text{ Mcal ME}}{\text{lb. forage}} = 23.5 \text{ lbs. forage}$$

This would leave .5 lbs. of forage for gain, which would supply .17 Mcal of NE_g. The cow should be able to gain .08 lbs. per day with this level of milk production and forage quality.

.5 lbs. of forage remaining

$$\bullet \frac{.34 \text{ Mcal } NE_g}{\text{lb. of forage}} = .17 \text{ Mcal } NE_g$$

$$.17 \text{ Mcal } NE_g \div \frac{2.1 \text{ Mcal } NE_g}{\text{lb. of gain}}$$

= .08 lbs. average daily gain

Table 3. Energy Content of Forages or Feeds at Different Digestibilities

	Dry Matter Basis	
Digestibility	Mcal ME/lb. of feed or forage	Mcal NE_g/lb. of feed or forage
40	.66	.04
42	.69	.07
44	.72	.10
46	.75	.13
48	.79	.16
50	.82	.19
52	.85	.22
54	.88	.25
56	.92	.28
58	.95	.31
60	.98	.34
62	1.02	.37
64	1.05	.40

TDN = Total Digestible Nutrients; ME = metabolizable energy; NE_g = net energy for gain; Mcal = megacalories or 1,000,000 calories.

COW HERD ASSESSMENT

The easiest way to monitor cattle is to use the body condition scoring system displayed in Table 4. Briefly, if the transverse processes of the lumbar vertebrae (between hip bones [hooks] and the ribs) are readily visible, the cow is probably a body condition score (BCS) of 3 and may not rebreed. Research has shown that reproduction will suffer when cows have a body condition score less than 4. Each 1 unit increase in body condition is approximately 80 pounds, so to increase a cow from a BCS of 3 to 4 would require a live weight gain of 80 lbs. Before a cow can gain weight, maintenance and lactation energy requirements must be met. It is practically impossible and very costly for cows to gain weight during early lactation. Most cows will mobilize fat to support milk production for the first 40 to 60 days of lactation. A good management practice is to monitor body condition 3 months before calving and supplement accordingly to maintain desired body condition. If possible, cattle should be at a BCS of 5 or greater at calving to allow for weight loss during the first 60 days of lactation. Young growing cattle that will be producing their first calf at calving, large frame size cows, and cows with greater milk production potential are all at risk for becoming thin and failing to rebreed. If the grazing management plan will allow it, young or thin cattle should be separated from the rest of the herd into a different pasture and supplemented as necessary to maintain body condition

Table 4. System of Body Condition Scoring (BCS) for Beef Cattle

Group	BCS	Description
Thin Condition	1	EMACIATED - Cow is extremely emaciated with no palpable fat detectable over spinous processes, transverse processes, hip bones or ribs. Tail-head and ribs project quite prominently, as do shoulders, hooks, backbone, and pins. Looks like C.M. Russell's "Waiting for a Chinook" or "Last of the 5000."
	2	POOR - Cow still appears somewhat emaciated, but tail-head and ribs are less prominent. Individual spinous processes are visible and sharply defined and are still rather sharp to the touch, but some tissue cover exists along the spine. Spaces between spinous processes are visible.
	3	THIN - Ribs are still individually identifiable but not quite as sharp to the touch. There is obvious palpable fat along spine and over tail-head with some tissue cover over ribs, transverse processes, and hip bones. Backbone is still visible but not so sharp in appearance. Transverse processes of lumbar vertebrae (between hooks and ribs) are readily visible. Hindquarters are angular in appearance and not fleshy.
Borderline Condition	4	BORDERLINE - Individual ribs are no longer visually obvious. Foreribs are not visible, but 12th and 13th ribs (last ribs) are. The spinous processes can be identified individually on palpation, but feel rounded rather than sharp. Some fat cover over ribs, transverse processes, and hip bones. Transverse processes are no longer obvious. Spine is covered with some fat, but it is still possible to detect individual vertebrae. Full, but straight, muscling in hindquarters.
Optimum Moderate Condition	5	MODERATE - Cow has generally good overall appearance. Upon palpation, fat cover over ribs feels spongy and areas on either side of tail-head now have palpable fat cover. The 12th and 13th ribs not visible unless the animal has been shrunk. Areas on each side of tailhead are beginning to fill with fat, but are not mounded.
	6	HIGH MODERATE - Firm pressure now needs to be applied to feel spinous processes. A high degree of fat is palpable over ribs and around tail-head. Back appears rounded. Hindquarters are plump and full. Noticeable sponginess over foreribs and small mounds of fat are beginning to appear beside tailhead.
	7	GOOD - Cow appears fleshy and obviously carries considerable fat. Very spongy fat cover over ribs and around tail-head. In fact, "rounds" or "pones" or "love handles" beginning to be obvious. Some fat around vulva and in crotch. Brisket is full. Spine is covered with fat and spinous processes can barely be distinguished. Back has a square appearance.
Fat Condition	8	FAT - Cow very fleshy and over-conditioned. Spinous processes almost impossible to palpate. Cow has large fat deposits over ribs, around tail-head, and below vulva. "Rounds" or "pones" are obvious. Very full brisket.
	9	EXTREMELY FAT - Cow obviously extremely wasty and patchy and looks blocky. Tail-head and hips buried in fatty tissue and "rounds" or "pones" of fat are protruding. Bone structure no longer visible and barely palpable. Animal's motility may even be impaired by large fatty deposits. Heavy deposits of udder fat.

Adapted from Richards et al., 1986; *Journal of Animal Science* Vol. 62:300.

at a score of 4 or greater prior to calving. Many producers also breed heifers to calve 30 days before the cow herd to allow them additional time to recover from the stresses of lactation prior to rebreeding. A producer should consider implementing a supplementation program if the forage is such that cattle are consistently at less than a BCS of 4 at breeding and conception rates are 10 to 15% lower than desired.

EXAMPLE OF COST OF BODY WEIGHT GAIN BEFORE CALVING

It is determined that several cattle are at a body condition score of 3, ninety days before calving. The grazing management plan does not allow separation of thin cattle into a separate pasture. The permittee desires to evaluate the economics of supplementing all 100 cattle. To increase body weight 80 lbs. (1 condition score) over 90 days requires an average daily gain of .88 lbs. It is assumed that at 55% digestibility, the forage is currently meeting maintenance requirements if cattle have daily forage intakes equal to 2% of their body weight. The NE_g content of the cottonseed meal supplement to be fed is .50 Mcal of NE_g per lb. If cottonseed meal was $180 per ton and 90% dry matter (DM), to gain .88 lbs. per day would require feeding 4.11 lbs. of protein supplement per day at a cost of $0.37 a day.

$$\frac{.88 \text{ lbs gain}}{\text{day}} \cdot \frac{2.1 \text{ Mcal } NE_g}{\text{lb. gain}}$$

$$= \frac{1.85 \text{ Mcal } NE_g \text{ required}}{\text{day}}$$

$$\frac{1.85 \text{ Mcal } NE_g}{\text{day}} \div \frac{.50 \text{ Mcal } NE_g}{\text{lb. cottonseed meal}}$$

= 3.7 lbs DM cottonseed meal

3.7 lbs. DM cottonseed meal

$$\div \frac{.90 \text{ dry matter}}{\text{lb. as fed cottonseed meal}}$$

= 4.11 lbs. as fed cottonseed meal

$$\cdot \frac{\$0.09}{\text{lb.}} = \$\ .37 \text{ per day}$$

The 90 day cost per cow would be $33.30, or $3330 for 100 cows. If conception rates increased only 10% by increasing body condition by 1 unit, the value added for calves would be $3000 if calves weighed 400 lbs. at weaning and sold for $0.75 per lb. If labor is factored in at $20 per day to feed the supplement and supplement was fed three times per week (9.59 lbs. per cow per feeding), net loss would be $930.

[$3330 supplement cost + $600 labor and gas (3 times/ week feeding)] - ($3000 value from calves) = $930 loss

In order to break even on the cost of supplement + labor and gas in the above scenario, two-thirds of the cow herd would need to be at a body condition of 3.

$3930 total cost of supplementation ÷ $300 per calf = 13.1 calves

13.1 calves ÷ 20% conservative estimate of increased conception with cow BCS of 4 vs. 3 during breeding = 65.5 cows

It is much more cost effective to separate thin cows from fat cows 3 to 4 months before calving, and to supplement them to be at a BCS of 5 or greater at calving. Ideally, cattle should go into winter with a BCS of 5 or greater. This allows for a cushion for weight loss when forage quality and availability decline. Thin cows, especially first calf heifers, could possibly benefit from weaning calves 1 or 2 months early to take advantage of lower cow maintenance requirements and the opportunity for gain before forage quality and availability drop in late fall. If first calf heifers have calved two weeks to a month before the cow herd, this can offset some of the reduced weaning weight. Also, late summer calf prices are often slightly higher than autumn calf prices. Producers can benefit by evaluating forage as described below in order to match cow nutritional requirements to forage quality. This will allow for forward planning of weight loss in the cow herd and enable designing a cost effective supplementation program.

FORAGE ASSESSMENT

*Forage Quality***.** In order to match cow requirements to the available forage, lab analyses of forage samples representative of the cow herd diet are encouraged. By matching cow nutritional requirements with forage contributions, a cost effective supplement program can be developed. When forage is green and actively growing, forage quality should be sufficient to meet a cow's nutritional requirements. As forage matures, forage quality is reduced substantially. At a minimum, the forage should be analyzed for protein and TDN, and, if possible, calcium and phosphorus. Local Cooperative Extension offices can furnish addresses and phone numbers of laboratories which can provide this service.

Another option to plant testing is to analyze fecal samples from a cross section of the herd (approximately 10 cows) using a new technique called near infrared spectroscopy (NIRS). This technique uses reflected infrared light to estimate digestibility, protein, and phosphorus content of the forage diet. Unless the cow's diet contains 30% or greater brush content, NIRS can be a rapid and easy method to determine nutrient content of the diet. Currently, Texas A & M University (Department of Rangeland Ecology and Management, Grazingland Animal Nutrition Lab, College Station, TX 77843-2126) is doing this procedure. The phone number for more information is (409) 845-5838.

Currently, the cost for protein and TDN plant analyses is approximately $18, and the cost for NIRS is around $24 with shipping costs included. The NIRS procedure may more accurately estimate energy and protein content of the selected diet, but is not recommended when diets consist of large quantities of brush. If plant analysis is practiced, it is important to select a representative sample similar to what the cows are actually eating by plant species and percentage.

Benefits are not usually realized in nonlactating cattle for protein supplementation unless the forage has less than 6.25% protein. Protein supplementation when protein content of the forage is below this level will increase microbial synthesis of protein in the rumen and also increase passage rate and intake of poor quality forage. If forage has less than .28% calcium and .22% phosphorus as a percentage of dry matter, then lactating cattle (1000 lbs.) should have a free choice calcium and phosphorus mineral mix provided in addition to trace mineral salt. The TDN or digestibility content of the forage for lactating cattle is marginal at around 56%. For nonlactating cattle, TDN is marginal at around 52%. As digestibility of the forage drops, residence time in the rumen increases and forage intake decreases to levels inadequate to maintain production and reproductive success.

*Additional Considerations for Forage Quality***.** Let us assume a cow herd consists of 1200 lb. cows milking 16 lbs. per day and that forage quantity is no problem. The cows' maintenance and lactation energy requirements would be equal to 20.5 + 7.7 Mcal or 28.2 Mcal of ME per day (Table 2). If the forage digestibility is 60% (green and actively growing), then the energy concentration for maintenance would be .98 Mcal of ME per lb. of forage (Table 3). This would equal 29 lbs. of forage per day that needs to be eaten to maintain body weight, or 2.4% of body weight. This level of intake is possible with forage quality this good. If forage quality dropped to 54% digestibility, then forage intake would need to be 2.7% of body weight, which is probably not possible with forage of this quality. In this instance, the cow would need to reduce milk production or lose body weight, or both. If the cow had a body condition score of 6, then weight loss would probably not be a problem. However, if the cow had a body condition score of 4, then potential problems could exist for rebreeding.

Because minimal cheap harvested feed or crop aftermath exists in Arizona, it is probably advantageous to match yearly forage resources to the calving season to reduce supplemental feeding. If a sufficient quantity of nutritious green spring forage is available, then traditional spring calving is practical. On the other hand, if forage quantity is limiting and often of poor quality during early spring, then it may be advantageous to move the calving season forward to synchronize with summer monsoon rains. Nonlactating cattle will consume about 30% less forage than lactating cattle and forage quality of dormant forage will more closely match nutrient requirements for nonlactating cattle.

SUPPLEMENTATION DECISIONS

Once the cow requirements are defined and forage quality determined, a decision can be made to supplement protein or energy or both. Usually, the best practice is to satisfy protein requirements first. This gives the best chance for increasing forage intake and increasing energy intake. After protein requirements are met, additional protein and energy may need to be supplemented in order to meet energy requirements or for weight gain. If the allotment is accessible, supplementation may have positive economic benefits in subsequent calving percentages. Supplemented cattle should be monitored frequently for body condition to evaluate the success of the supplementation program.

*Energy Supplementation***.** If the energy content of the forage is deficient, supplementation of energy will decrease forage intake and possibly forage digestibility. This may sometimes be an advantage in stretching forage supplies. Some of the negative forage substitution effects of energy supplementation upon forage intake can be overcome by including greater proportions of feed byproducts high in fiber such as corn gluten feed in the energy supplement. Energy supplements also have the disadvantage of needing to be supplemented at least every other day, and preferably every day. This may be impractical for many range operations. Boss cows may overload with energy when supplemented at less frequent intervals. Salt-limited supplements are also an option, but oftentimes cost discounts are not applied to the commercial supplement for the 20% salt included. Another solution may be to feed molasses based blocks, but an economic analysis should be conducted to determine costs and benefits of this type of energy supplement.

Protein Supplementation. Due to its positive effects upon forage intake, protein supplementation is the most frequently practiced of all supplementation regimes. Research in west Texas has shown that cattle may be effectively supplemented with protein as infrequently as once a week (seven times daily rate of supplementation of 2 lbs. per day). As mentioned earlier, protein supplementation may increase forage intake, allowing for greater intake of nutrients. Since protein supplements are costly, forage evaluation is recommended to determine if protein supplementation is necessary. For nonlactating cattle, the forage should contain less than 6.25% protein. Lactating cattle may benefit from protein supplementation if forage is below their requirements (9.6% for 1000 lb. cow), but they should be able to tolerate a slight deficiency since they can select a diet higher in protein than random pasture clippings. If forage availability is inadequate, protein supplementation may be inefficient. If forage utilization in a pasture is already at 50%, then don't expect protein supplementation to enhance forage intake. Managers who use protein supplementation effectively with dormant forages often do so by establishing ungrazed forage "banks" or pastures to use in conjunction with protein supplementation. By doing so, the manager ensures adequate forage availability. If forage availability is inadequate, feeding larger quantities of a protein-energy supplement would be a better choice to attempt to minimize weight loss.

*Bypass Protein Supplementation***.** If the cow herd has been experiencing pronounced loss of body condition and the energy content of the forage is adequate, supplementation with a ruminally undegradeable protein supplement or bypass protein may be advantageous. Research in Montana on dormant winter range has shown that the feeding of bypass protein supplements may reduce weight loss in stressed cows. Also, earlier estrus activity following calving may exist in cows fed bypass protein. Feedstuffs high in bypass protein include feather meal, blood meal, corn gluten meal, and fish meal. Due to palatability problems, rendered animal products are usually limited to 25 to 30% of the total supplement and are combined with grain products to increase palatability. The effectiveness of bypass protein is influenced by the type of forage. For instance, research in Texas reported that cottonseed meal contains 50% bypass protein when fed with cool season forages, but only 23% with warm season forages. The disadvantage with feeding bypass protein is cost. Bypass protein supplements may cost twice as much as normal protein supplements.

Table 5. Protein and Energy Content of Some Supplements

	Dry Matter Basis		
Feedstuff	% Protein	ME, Mcal/ lb.[a]	NE_g, Mcal/ lb.[a]
Corn	10.0	1.49	.67
Milo	12.4	1.30	.58
Cottonseed Meal	44.8	1.23	.50
Alfalfa Hay, full bloom	15.9	.85	.22

[a]ME = metabolizable energy; Mcal = megacalories (1,000,000 calories); NE_g = net energy for gain.

*Supplement of Indecision***.** Sometimes a producer is unsure whether to supplement protein or energy. Usually, when forages are low in energy, they are also low in protein. Cool season forages tend to have greater digestibility than warm season grasses. Dormant Tobosa grass can be very low in both digestibility and protein. The "supplement of indecision" combines both protein and energy. An example supplement would contain 40% natural protein, 50% grain products, trace mineral salt, vitamins A and D, dicalcium phosphate, and potassium chloride. Fed at a rate of 2 pounds a day the 90 days preceding calving, there would probably be a slight decrease in BCS if the forage was low in protein and forage availability was adequate.

EXAMPLE CASE STUDIES OF SUPPLEMENTATION

As mentioned previously, supplementation of cattle should occur before calving. Minimal results will be achieved through supplementation the first 45 to 60 days after calving, and attempting to restore body condition after this time will be twice as costly as supplementing for weight gains before calving.

Two examples are presented at the end of this section: I. Maintaining a cow at a BCS of 5, ninety days before calving when forage quality is inadequate; and, II. Increasing BCS from 4 to 5, seventy days before calving when forage quality is adequate.

Table 5 provides nutrient content of some feedstuffs. Other values can be obtained from National Research Council tables for feedstuffs or from your feed company. Least cost computer programs are also available to calculate the least expensive supplements to feed.

SUMMARY

Ideally, body condition of cattle should be 5 or greater for maximum reproductive success. If BCS drops below a score of 4 at breeding, calving percentages will decrease sharply.

Producers should manage their herds through supplementation regimes to obtain at least a BCS of 5 at calving. The least costly and most effective time to supplement is before calving. If cattle are still thin at calving, they should be placed on a higher plane of nutrition at least 60 to 90 days to increase conception rates. This may be accomplished with higher quality pastures if available or supplementation or both. Forage which is not green and actively growing should be analyzed to determine what type of supplementation to practice and at what level.

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Example I. Maintaining a Cow at BCS of 5 with Inadequate Forage Quality

1. **Determine Forage Quality.**
   Forage digestibility is 50% and protein is 6.2%.

2. **Determine Cow Maintenance Requirements (Table 2).**
   For a 1000 lb. nonlactating cow in the last trimester of pregnancy, 18 Mcal of ME and 1.6 lbs. protein are required.

3. **Estimate Forage Intake (Table 1).**
   Forage intake is estimated at 1.8% of body weight (a little less since cow is nonlactating).

4. **Determine if Maintenance Requirements are Being Met.**
   Protein: 18 lbs. forage intake • .062 protein in forage = 1.116 lbs. The forage is deficient in protein by .484 lbs. (1.6 - 1.116 = .484 lbs.) Using cottonseed meal as a supplement would require 1.08 lbs. of cottonseed meal per day (Table 5, dry matter basis). (.484 ÷ .448 protein/lb. cottonseed meal = 1.08 lbs.)

   Energy: 18 lbs. forage intake • .82 Mcal ME per lb. (see Table 3 to convert TDN to ME) = 14.76 Mcal. The forage is deficient by 3.24 Mcal. (18 - 14.76 = 3.24 Mcal). Using cottonseed meal as supplement would require 2.63 lbs. of cottonseed meal per day (Table 5, dry matter basis). (3.24 ÷ 1.23 Mcal ME/lb. cottonseed meal = 2.63 lbs.)

   So, to satisfy the maintenance requirements of this cow would require about 2.9 lbs. of cottonseed meal per day. (Must convert dry matter to as fed basis: 2.63 ÷ .90 dry matter = 2.9 lbs.)

5. **Supplement for Maintenance if Necessary.**
   To supplement this cow at this level for 90 days preceding calving would require 2.9 lbs. of protein supplement per day for a cost of $ .25 per day or $22.50 for 3 months ($9.00 per cwt. for cottonseed meal).

6. **Determine if Body Condition is Adequate.**
   Adequate.

7. **Supplement for Weight Gain if Needed.**
   Not needed.

8. **Financial Analysis.**
   If a 10% increase in conception occurs as a result of supplementation and calves are born on an average 20 days earlier, then the net profit excluding labor and gas is $19.50 (400 lb. weaning weights; 1.5 lbs. average daily gain on calves).

20 days • 1.5 ADG • .60/lb. =	$ 18.00
10% increase in conception: (400 lbs. • .60/lb • .10)	24.00
	42.00
less supplement cost	- 22.50
profit exc. labor and gas	$ 19.50

Example II. Increasing Cow Condition from 4 to 5 with Adequate Forage Quality

1. **Determine Forage Quality.**
   Forage digestibility is 55% and protein is 8.5%.

2. **Determine Cow Maintenance Requirements (Table 2).**
   For a 1000 lb. nonlactating cow in the last trimester of pregnancy, 18 Mcal of ME and 1.6 lbs. protein are required.

3. **Estimate Forage Intake (Table 1).**
   Forage intake is estimated at 2.0 % of body weight.

4. **Determine if Maintenance Requirements are Being Met.**
   Protein: 20 lbs. forage intake • .085 protein in forage = 1.7 lbs. The forage is adequate in protein.

   Energy: 20 lbs. forage intake • .90 Mcal ME per lb. (see Table 3 to convert TDN to ME) = 18 Mcal. The forage is adequate in energy.

5. **Supplement for Maintenance if Necessary.**
   Not necessary.

6. **Determine if Body Condition is Adequate.**
   Inadequate. Needs to increase by 1 condition score before calving, or by 80 lbs.

7. **Supplement for Weight Gain if Needed.**
   Average daily gain needed over 70 days is 1.14 lbs. (80 lbs. ÷ 70 days = 1.14 lbs.) This requires 5.3 lbs. of cottonseed meal per day (as fed basis). (1.14 lbs. ADG • 2.1 Mcal NE_g required per lb. of gain = 2.394 Mcal NE_g; 2.394 Mcal NE_g required ÷ .50 Mcal NE_g per lb. of cottonseed meal (Table 5) = 4.788 lbs. cottonseed meal (dry matter basis); 4.788 lbs. ÷ .90 dry matter = 5.3 lbs. cottonseed meal per day.

8. **Financial Analysis.**
   In this example, weight gain is expensive using a protein supplement. If a cheaper protein supplement could be obtained with a higher NE_g concentration per lb. of supplement, then it would cheapen things somewhat. Also, a judgment call is required here. In most years, the substitution of grain products could cheapen the cost of gain by about 1/2. There may be some decline in forage intake (possibly up to 15%), but this can be alleviated somewhat by feeding the grain supplement during the early afternoon (around 1 PM). Unless the weather is cold, cattle should not be grazing as actively during this time period, so there will be less substitution of energy obtained from the grain for energy obtained from grazing. If the protein supplement was fed, then the gross profit before discounting labor and gas would only be $8.50 per cow. This may be marginal in profitability. If corn were fed, 4 lbs. of corn would be required per day to achieve the same weight gains. At a corn price of $7.50/cwt, the cost per day for corn would be around $0.25 to $0.30 per day or $17.50 to $21.00 for the feeding period.

For Protein Supplement		**For Grain Supplement**	
20 days • 1.5 ADG • .60/lb. =	$ 18.00	20 days • 1.5 ADG • .60/lb. =	$ 18.00
10% increase in conception:	24.00	10% increase in conception:	24.00
(400 lbs. • .60/lb • .10)		(400 lbs. • .60/lb • .10)	
	42.00		42.00
less protein supplement cost	- 33.60	less grain supplement cost	- 21.00
profit exc. labor and gas	$ 8.40	profit exc. labor and gas	$ 21.00

FROM:

Arizona Ranchers' Management Guide
Russell Tronstad, George Ruyle, and Jim Sprinkle, Editors.
Arizona Cooperative Extension

PROTEIN SUPPLEMENTATION

Jim Sprinkle[1]

INTRODUCTION

Arizona can be characterized as having a bimodal (occurring twice a year) pattern of forage production which accompanies the seasonal summer monsoons and winter rains or snows. Forage quantity and quality decrease during the winter dormant season and the "summer slump" preceding summer rains (Figure 1). However, forage quality during any given month can be quite variable, depending upon the timing, frequency, and amount of moisture. This is illustrated in Table 1.

DETERMINING WHEN TO SUPPLEMENT PROTEIN

Generally speaking, crude protein content required in the forage to meet the requirements of rumen microbes that digest fiber is around 7%. When crude protein in forage is below 6.25%, forage intake for the nonlactating cow drops sharply (Figure 2).

Providing supplemental protein when crude protein is less than 6.25% can increase forage intake and sometimes forage digestibility, reduce weight loss before calving, and ultimately increase conception rate and profitability.

If the Total Digestible Nutrients (TDN) of forage is around 52 to 55%, forage intake required to maintain a nonlactating cow is around 1.8 to 2.1% of body weight or around 18 to 20 lbs. This is true if protein requirements are being met by the forage or by feeding supplemental protein. If protein is deficient in the diet, severe weight loss can occur since the cow must break down body tissue to supply the necessary protein. It takes 6.7 lbs. of lean tissue to supply 1 lb. of protein (Berg and Butterfield, 1976). Conversely, if the diet is deficient in energy (TDN), this only requires 1 lb. of body weight loss for each 1 lb. of TDN (NRC, 1989).

As shown in Figure 2, when forage fails to meet protein requirements of the microbes in the rumen, intake decreases. This is because microbe numbers and (or) microbe activity decrease, reducing forage digestibility and increasing exit time from the rumen for fiber. When the forage only contains 4% crude protein, Figure 2 projects forage intake of only 1.2% of body weight. Forage intake at this level would cause extreme weight loss. Ignoring

Figure 1. Forage Production in Arizona

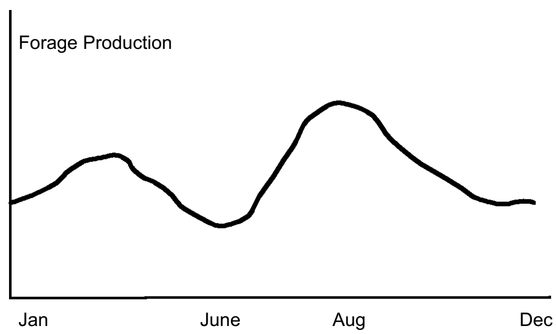
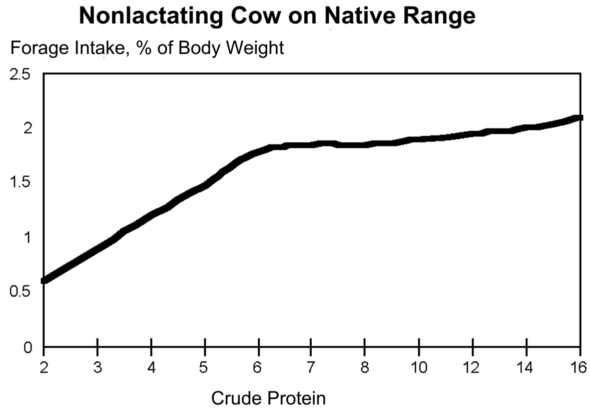


Table 1. Range In Crude Protein by Month
Blue Gamma in Arizona

Month of Year	Number of Observations	Crude Protein, %
January	2	3.94 - 7.55
February	5	1.58 - 6.9
March	3	2.57 - 7.3
April	3	4.55 - 7.9
May	5	1.92 - 9.3
June	3	5.59 - 9.0
July	4	4.45 - 8.6
August	6	4.42 - 9.43
September	4	4.76 - 12.5
October	2	6.0 - 7.4
November	7	3.03 - 6.7
December	2	4.5 - 7.13

1979, 1980-81,1995-96

Figure 2. Effect of Crude Protein on Forage Intake



Adapted from: Cochran, 1995 KSU Range Field Day.

Table 2.Cottonseed Meal Supplementation

Steers Fed 6% Crude Protein in Prairie Hay

Environmental Group	Rumen Digestibility	Forage Intake Increase	Net Effect
Supplemented	57.5%	+ 27%	+ 27% increase in nutrient intake
Control	56.6%		

McCollum and Galyean, 1985 *Journal Anim. Sci.* 60:570–577.

Table 3. Protein Supplementation with Cottonseed Meal

Steers Grazing Tobosa

Amount CSM, lbs.	Cost/Day (.114¢/lb.)	ADG	Extra Gain with CSM	Profit/Day (.70/lb. calf)
1985*	*(Crude protein below 7% in July)			
0	0	0.84		
0.75	0.09	0.97	0.13	0
1.5	0.17	1.48	0.64	0.28
1986				
0	0	1.43		
0.75	0.09	1.45	0.02	-0.07
1.5	0.17	1.57	0.14	-0.07
1987				
0	0	2.16		
0.75	0.09	2.38	0.22	0.07
1.5	0.17	2.36	0.20	-0.03

Adapted from Pitts et al., 1992: *Journal Range Mgmt.* 45:226-231

deficient protein and only considering the energy deficit, weight loss in the above example could exceed 4 lbs. per day.

As a general rule, do not supplement protein when the forage contains greater than 6.25% crude protein (Caton et al., 1988). However, benefits will be gained by protein supplementation when crude protein in forage is low. This principle is illustrated by Tables 2 and 3. In the first example (Table 2), forage intake and overall nutrient intake increased by 27% when steers on a 6% crude protein hay diet received additional protein. In the second example (Table 3), supplementing steers grazing tobosa grass was only beneficial when the forage contained less than 7% crude protein.

Obviously, the only way to decide if you need to supplement crude protein or not is to test forage for protein content. Your local Extension office can provide a list of commercial labs which perform this service. The cost for crude protein and TDN analyses totals around $18. Alternatively, near infrared spectroscopy (NIRS) analyses can be performed on fecal samples provided the cow's diet does not exceed 30% brush. This service is provided by Texas A & M University Grazingland Animal Nutrition Lab at College Station, TX (phone 409-845-5838).

It should be mentioned that protein supplementation is only effective when an adequate quantity of forage is available. The strategy with supplementing protein is to feed the microbes enough protein to enable the cow to more effectively process and harvest cheap, low quality forage. When forage utilization (removal of available quantity by livestock, wildlife, and insects) exceeds 50% of the total mass, protein supplementation may be ineffective and expensive. In this scenario, it would be more advantageous to feed a combination protein/energy supplement. The next two graphs support this point. In the first graph,

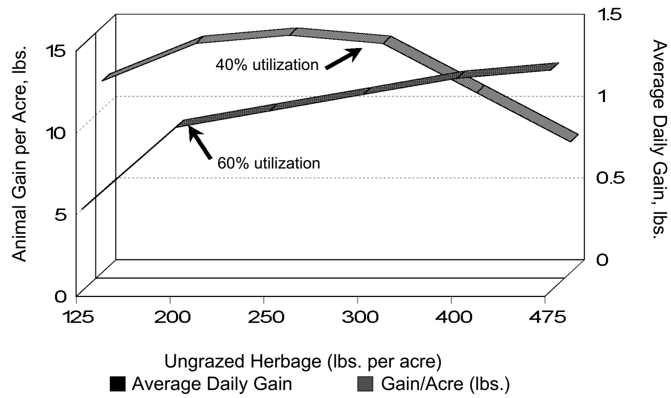
(Figure 3) researchers found that maximum animal gain per acre was achieved when forage utilization was 40 to 50%. Animal performance dropped sharply when forage utilization reached the 60% level. The standard rule of range management for plant health is “to take half and leave half.” This is also good animal management. In the second graph (Figure 4), an experiment was conducted with protein supplementation on mid-grass prairie at two different stocking rates. In the heavy stocking rate regime, protein supplementation was not economically sound.

The ideal time to supplement protein in terms of a cow’s physiological cycle is 60 to 90 days before calving. This is the time period when maintenance requirements are low and you receive the biggest “bang for your buck” in preventing weight loss and increasing conception rate. In most of Arizona with traditional spring calving, this accompanies the forage winter dormancy period. It is an expensive proposition to try to put on weight after calving, as Mother Nature is working against you. The demands of early lactation induce weight loss which is almost impossible to reverse until after about day 45 to 60 of lactation. It is a more cost effective practice to have the cow maintain or put on weight before calving to provide a safety cushion for weight loss. Table 4 illustrates the importance of having cattle in good body condition at calving.

This research was done with two-year-old cows in LA, OK, and SC, but the results are similar to those in other states. If in spite of your best efforts, cattle are thin at calving, opportunities may exist to “flush” British and Continental cross cattle with better quality pastures and (or) supplements following peak lactation (around 60 to 70 days). This stage of lactation would accompany the forage “summer slump” time period for many Arizona ranching operations. If cattle have sufficient body fat reserves at calving they may safely coast through the summer slump and

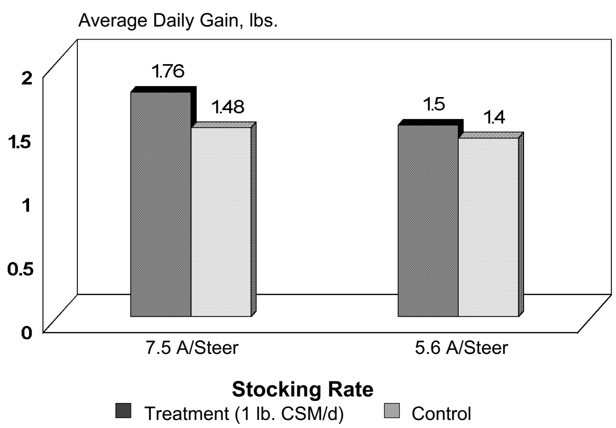
Figure 3. Animal Performance and Stocking Rate

Upland Blue Grama Range in Colorado



Adapted from: Bement, 1969 *Journal of Range Mgmt.* 22:83-86.

Figure 4. Effect of Stocking Rate Upon Cottonseed Meal Supplementation



McCollum et al., 1992 Marvin Klemme Range Res. Sta. Report, OK

Table 4. Pregnancy % by Body Condition Score

Body Condition at Calving	Day 40 of Breeding Season	Day 60 of Breeding Season
4	43 ± 5	56 ± 5
5	65 ± 4	80 ± 4
6	90 ± 9	96 ± 8

Spitzer et al., 1995 *Journal of Animal Science* 73:1251–1257 maintain acceptable conception rates. However, if cattle are below a body condition score of 4 at breeding time, it may be time to consider using a protein supplement if forage quality is low. Unfortunately, flushing thin cattle following peak lactation does not seem to work for Brahman cross cattle. Research in Australia has shown that lactating Brahman cattle often put the energy obtained from supplements into milk production instead of body fat (Hunter, 1991). This would suggest that the only opportunity one has for increasing fat stores for grazing Brahman cross cattle is before calving.

HOW MUCH SUPPLEMENT TO FEED

The most cost effective method in feeding protein supplements is to supplement what is deficient in the forage (amount of protein required by animal – amount contained in forage). Guidelines for doing this are contained in another article in this guide entitled, *Matching Forage Resources with Cow Herd Supplementation*. I have listed the maintenance requirements for a 1000 lb. cow in Table 5, but requirements will differ for different size cows. As an example in calculating the amount of protein to supplement, forage crude protein was tested and found to be 4%. For a 1000 lb. nonlactating cow, the amount of protein which needs to be fed was 2.32 lbs. per day and is calculated as follows:

1. Find the daily requirement, which is 1.6 lbs.
2. Determine the amount contained in forage. If we estimate forage intake to increase to 1.7% of body weight for the supplemented cow, then crude protein in the forage is .68 lbs. (1000 x .017= 17 lbs; 17 x .04 crude protein in forage = .68 lbs. protein)
3. Subtract the amount contained in forage from the daily requirement, which gives .92 lbs. of protein which needs to be supplemented. (1.6 – .68 = .92 lbs. of protein needed)
4. Determine the amount of supplement to feed by dividing the amount of protein needed by the protein content of the supplement. If we feed cottonseed meal (44% crude protein), then we need to feed 2.09 lbs. of cottonseed meal on a dry matter basis. (.92 lbs. protein needed ÷ .44 lbs. protein/lb. cottonseed meal = 2.09 lbs. cottonseed meal)
5. Since most protein supplements contain about 10% water, convert feed on a dry matter basis to an "as fed" basis. This would require the feeding of 2.32 lbs. of cottonseed meal per day to meet protein requirements. (2.09 ÷ .9 = 2.32 lbs. cottonseed meal)

Table 5. Maintenance Requirements of Range Cattle

	Energy TDN	Protein % in diet or lbs.
Nonlactating, Mid-Pregnancy	9.1 lbs.	7.0 or 1.40
Nonlactating, Last Trimester	11.0 lbs.	7.9 or 1.60
Early Lactation, 18 lbs. milk	16.5 lbs.	11.0 or 2.24
Mid-Lactation, 10 lbs. milk	14.0 lbs.	9.6 or 2.00
Late Lactation, 7 lbs. milk	12.8 lbs.	9.5 or 1.90

(1000 lb. cow)

The protein could be fed once a week (7 times the daily rate) without harming the cow (Huston et al., 1999). Ruminant animals have an ability to recycle some of the excess nitrogen contained in protein back into the rumen after it is consumed the first time (Owens and Zinn, 1988). **Do not feed energy (high grain, protein less than 22%) supplements with less than daily feeding or problems like acidosis and founder can occur.**

WHAT KIND OF PROTEIN SUPPLEMENT TO USE

The greatest benefits for protein supplements are usually obtained with high protein of a natural origin (no protein from urea). These type of supplements are also the most expensive to use. A portion of the protein can be obtained from urea in order to cheapen the protein supplement. Too much urea in the supplement can result in reduced intake of the supplement due to palatability problems or urea toxicity if cattle consume too much of the supplement. Recommendations for urea substitution of natural protein will be discussed later.

It is important to know the ideal composition of protein supplements to feed. Although we know very little concerning the ideal amino acid profiles, research has identified the advantage of using supplements with greater crude protein. When five trials in Kansas were summarized, researchers found that increasing crude protein of the supplement from 15 to 22 to 28% resulted in 49% greater forage intake and 22% greater forage digestion (as cited in Paterson et al., 1996). Kansas researchers also found that cattle fed a 13% crude protein supplement lost 193 lbs. over the winter and cattle fed a 39% crude protein ration lost 97 lbs. over the winter (DelCurto et al., 1990).

In stressful situations in which cattle are losing weight, some benefits have been demonstrated by feeding supplements with approximately 40 to 60% of the protein being ruminally undegradable or bypass protein. Feedstuffs high in bypass protein include feather meal, blood meal, corn gluten meal, and fish meal. Due to palatability problems, rendered animal products are usually limited to 25 to 30% of the total supplement and are combined with grain products to increase palatability. Petersen et al. (1996) reported that weight loss has been reduced and conception rates increased in several experiments by feeding bypass protein. However, they reported that bypass protein supplementation only seems to be effective when animals are losing weight. The additional cost per ton for adding bypass protein is around $50 to $80.

When urea is substituted for natural protein in the supplement, it is recommended that no more than 30% of the crude protein in the supplement come from urea (Köster et al., 1996). Table 6 presents research data from Kansas showing a slight decrease in cow performance when the percentage of crude protein derived from urea was 30%. If forage quality is very low and the supply of forage limited (as in drought) avoid the feeding of any urea at all.

Table 6. Substitution of Urea for Natural Protein

Cows Grazing Winter Tallgrass Prairie

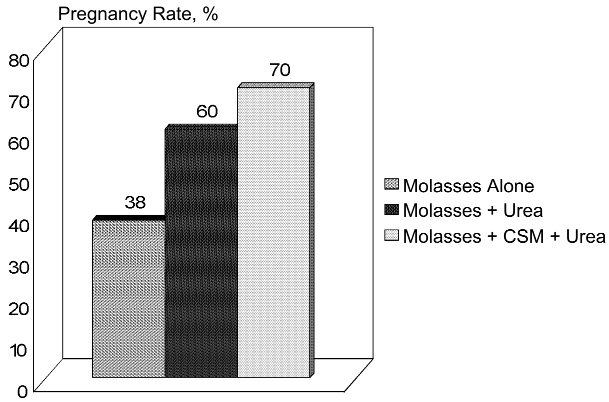
Item	0% CP from urea	15% CP from urea	30% CP from urea
Supplement Intake, lbs.	4.8	4.8	4.8
Wt. gain [28 Nov - 7 Feb]	48	42	14
Wt. gain [28 Nov - 21 Mar (Calving)]	-97	-107	-130
Wt. gain [28 Nov - 27 Apr (Breeding)]	-152	-152	-172
Wt. gain [28 Nov - 5 Oct (Weaning)]	52	62	27
Pregnancy Rate, %	92.6	100	86.2

Koster et al., 1996 KSU Cattemen's Day

Liquid feed supplements can be expected to have similar results to dry supplements. If the supplement does not contain sufficient protein (less than 22% crude protein) it can be expected to perform as an energy supplement. Usually, energy supplements result in substitution of forage by the supplement and can decrease both forage intake and forage digestibility (Caton and Dhuyvetter, 1997). Urea is often added to liquid supplements to increase crude protein. Modern technology has devised an urea molecule that breaks down more slowly than the urea molecule used in past formulations. This has reduced the danger of urea toxicity for liquid feeds. Assumptions made above for dry feeds on the percentage of urea included in feeds and their effect upon performance are probably valid for liquid feeds also. This is illustrated in Figure 5. Incremental increases in pregnancy rate were achieved by increasing protein of the molasses supplement by urea and then by cottonseed meal plus urea.

Figure 5. Molasses Supplements

3-Year-Old Cows Fed Stargrass Hay (4-6% CP)



Pate et al., 1990 *Journal Anim. Sci.* 68:618-623

Example 1: Deciding Which Supplement to Buy

Supplement A: Fed once/wk (2 lbs./d x 7 = 14 lbs/feeding)
Supplement B: Self fed (2.5 lbs/day)

1. Determine protein content of supplements:
   Supp. A: 44% CP x 2000 lb. = 880 lb. protein
   Supp. B: 36% CP x 2000 lb. = 720 lb. protein

2. Determine the cost/lb. protein:
   Supp. A: $228/T or 228 ÷ 880 lb. = $ .26/lb. protein
   Supp. B: $260/T or 260 ÷ 720 lb. = $ .36/lb. protein

3. Determine the cost of dispensing supplements:
   Supp. A: $70/T or 70 ÷ 880 = $ .08/lb. protein
   Supp. B: $20/T or 20 ÷ 720 = $ .03/lb. protein

4. Determine protein each cow eats each day:
   Supp. A: 2 lbs. x .44 = .88 lb. protein
   Supp. B: 2.5 lbs. x .36 = .90 lb. protein

5. Determine the cost/cow/day:
   Supp. A: .88 lbs. protein x (.26 + .08) = $ .34/day
   Supp. B: .90 lbs. protein x (.36 + .03) = $ .35/day

6. Determine the cost for the herd:
   Supp. A: $ .34 x 60 d x 100 cows = $ 2040
   Supp. B: $ .35 x 60 d x 100 cows = $ 2100

In a presentation given to the American Feed Industry Association in 1995, J.E. Moore made the following conclusions concerning the use of liquid feeds:

1. When forage quality was low, forage intake and average daily gain (ADG) increased, but ADG could still be low or negative.
2. When forage quality was high, forage intake decreased, but ADG increased if supplement contained meal + urea or meal.
3. Forage intake decreased if forage intake was greater than 1.75% of body weight.
4. Forage intake increased if forage intake was less than 1.75% of body weight.
5. Forage intake decreased if supplement intake exceeded .8% of body weight (about 8 lbs. for a 1000 lb. cow).
6. Forage intake increased when crude protein of the supplement was greater than 22%.
7. Liquid feeds acted similarly to dry supplements for forage intake.

DECIDING WHICH SUPPLEMENT TO BUY

The way to evaluate protein supplement purchases is to calculate the cost of each lb. of protein dispensed. Example 1 illustrates this for one supplement fed once a week at seven times the daily rate vs. another supplement that is self fed.

In Example 1, costs are similar, so a management decision needs to be made. If the producer desired to look at his herd more often, then he might opt for Supplement A. Otherwise, he may wish to use the self-fed supplement.

CONCLUSIONS

1. The purpose of protein supplementation is to feed microbes so the cow can harvest more cheap forage.
2. Adequate available forage is required for protein supplementation to be effective.
3. Forage should be tested to determine if supplementation is needed.
4. Young cows respond more favorably to protein supplementation than do older cows.
5. If forage is less than 6.25% crude protein (CP), protein supplementation typically increases forage intake, decreases weight loss, and increases conception.

6. The optimum time to supplement is 60 to 90 days before calving.
7. As a general rule, forage with 4% CP requires about 2 lbs. of cottonseed meal or soybean oil meal per cow per day.
8. To avoid hurting animal performance, keep CP by urea less than 30% of the total CP of the supplement.
9. Liquid feed functions much like dry protein supplements.
10. It is advisable to keep CP in supplements greater than 22% with low quality forage.

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FROM:

Arizona Ranchers' Management Guide
Russell Tronstad, George Ruyle, and Jim Sprinkle, Editors.
Arizona Cooperative Extension

SUPPLEMENTATION DURING DROUGHT

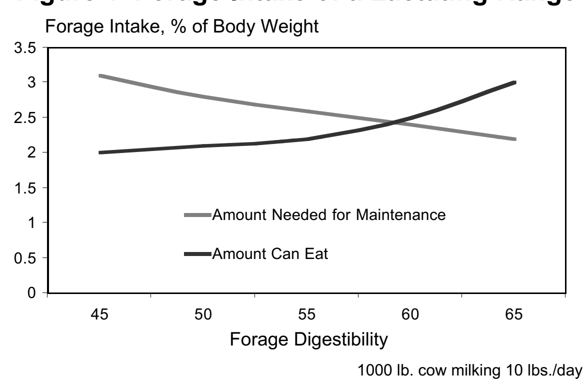
Jim Sprinkle[1]

INTRODUCTION

Breeding failure is the most important adverse consequence to the cow herd during drought. This is due to reduced forage quality and availability, resulting in nutritional stress. As forage quality decreases, lignin and other more slowly digestible components of forage increase. This lower quality forage remains longer in the rumen before exiting, reducing forage intake. Thus, the cow may be unable to eat enough forage to maintain body weight (Figure 1).

During early to mid-lactation, a beef cow will consume from 2.5 to 3.0% of her body weight in forage daily. During drought, stocking rates may be adjusted to increase forage for each animal unit, but forage quality may drop thereby preventing adequate digestible nutrient intake. As forage digestibility drops, passage rate of undigested dry matter decreases and forage intake declines. In Montana, when forage digestibility was 61%, lactating cattle consumed 2.2 to 2.8% of body weight in forage. During a drought year, forage digestibility dropped to 43% and the same lactating cattle consumed 1.2 to 1.3% of body weight in forage (Havstad and Doornbos, 1987). Forage intake at this level is inadequate to furnish the necessary nutrients for milk production and maintenance of cow body condition. To survive drought and maintain acceptable rebreeding percentages and economic viability, the cow herd should be managed for acceptable body condition. Forage should also be monitored for total production and

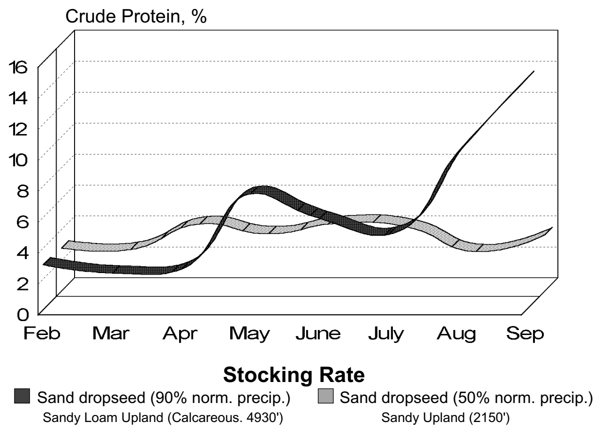
Figure 1. Forage Intake of a Lactating Range Cow



GENERAL RECOMMENDATIONS

1. Evaluate range to determine forage supply.
2. Analyze forage to determine nutrient deficiencies.
3. Start supplementation regime at least 60 days before calving to prevent accelerated weight loss following calving.
4. If forage supply is adequate (less than 50% utilization of forage), supplement natural protein (22% crude protein or greater) to meet forage deficiencies (generally 1 to 2 lbs. of supplement per day for nonlactating cattle). Protein supplements can be given as infrequently as once a week.
5. If forage supply is limited, use a protein/energy or energy supplement. Energy supplements need to be fed daily.
6. Use urea supplements with extreme caution.
7. Use water to help distribute livestock to underutilized areas of the grazing allotment.
8. Cull cows to match animal units to forage available. Cull in this order: open cows, old cows (9 years or older), 2-year-old producing cows, 3-year-old producing cows, replacement heifers.
9. Monitor use of toxic plants by cattle and move cattle if necessary to avoid over- consumption of toxic plants.

Figure 2. Crude Protein in Arizona During Drought



Arizona Strip Range Forage Quality Analysis Study (1996)

Table 1. Production from Cows During Drought

	No Supplement		1 lb./day cottonseed meal	
Cow Age (Years)	**Weaning Weight (Lbs.)**	**Conception Rate (%)**	**Weaning Weight (Lbs.)**	**Conception Rate (%)**
3	306	45	372	90
4	341	62	376	88
5	366	63	410	92
6	356	73	396	85

Foster, 1996

quality to determine if the cow's nutritional requirements are being met. It may be a cost effective practice to analyze forage or fecal samples for total digestible nutrients (TDN) and crude protein during dormancy or drought and match supplementation strategies to the nutritional deficits in the forage. Your local Cooperative Extension office can provide addresses of laboratories which offer this service.

PROTEIN SUPPLEMENTATION

Figure 2 illustrates crude protein content of sand dropseed (*sporobolus cryptandrus* (Torr.) Gray; warm season grass) at two different range sites in Arizona during the 1996 drought. At one site, precipitation was 90% of normal and protein content increased to 14.92% by September following 2.32 inches of moisture from July through September. At the lower elevation site with 50% of normal moisture, crude protein of the forage never got above 4.4%. At the same low elevation sandy upland range site, even winterfat had only crude protein above 6% for one month (April 96; 7.23% crude protein). Conversely, the crude protein of winterfat at the site with 90% moisture never fell below 6% and was above 11% during April and May. Protein required for a 1000 lb. nonlactating cow is around 1.6 lbs./ day or 7% crude protein in the diet. When the cow is lactating, 2.0 lbs. or 9.6% dietary crude protein is required. Drought accentuates the need for protein supplementation.

Protein supplementation during drought can yield dividends. In a study at Fort Stanton, NM over several years of drought, weaning weights and conception rates for cattle of different ages were compared (Table 1). The supplemented cows in this study were fed 1 lb. of cottonseed meal per day from just prior to calving until grass was green. The effects of the drought were most severe for younger cows, but supplementation increased weaning weights and conception rates in cows of all ages. Other cattle at risk during drought are heavier milking cattle and larger framed cattle. It is well to remember that during drought we are not only supplementing to meet deficits in this year's forage, we are also supplementing next year's calf crop.

When forage contains less than 6% protein, protein supplementation can be effective in enhancing forage intake (Caton et al., 1988). When additional protein is made available, this increases the number and activity of microorganisms in the rumen which are ultimately responsible for fiber digestion. As the microbial population of fiber digesting bacteria increases, passage rate of forage increases, ultimately allowing for greater intake of low quality forage. In some cases, greater digestibility of forage has also been observed. Figures 3 and 4 illustrate how both forage intake and forage digestibility were increased by protein supplementation for cattle eating poor quality (2% crude protein) prairie hay.

Steers fed the greatest amount of the 33% protein supplement increased forage intake 49% and had 39% greater digestibility of forage than control steers. The amount of TDN required to maintain body weight for nonlactating cattle is around 52%, so steers supplemented the highest level of protein should not have experienced weight loss (although these data were not reported).

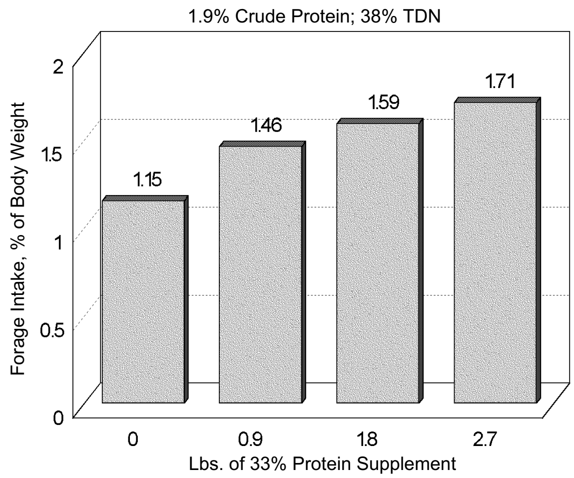
When a lower protein supplement (18%) was fed on an equal protein basis (1.7, 3.5, and 5.3 lbs. of supplement per day), forage intake was 1.34, 1.48, and 1.33% of body weight for each increasing supplementation level. Total ration digestibility was 41, 43, and 50%, respectively. Cattle in this study appeared to be limited in protein intake with the low quality forage, and substitution of forage by supplement did not appear to occur with the higher protein supplement. In this same study, some substitution of forage by supplement resulted when alfalfa hay was fed at the same rates as for the medium protein supplement. However, no substitution occurred when alfalfa pellets were fed, presumably because of a positive effect on rate of passage.

An advantage with protein supplementation is that cattle can be supplemented as infrequently as once a week without detrimental effect (Huston et al., 1997). This is not the case for energy supplements (e.g., corn, milo) which need to be supplemented daily.

ENERGY SUPPLEMENTATION

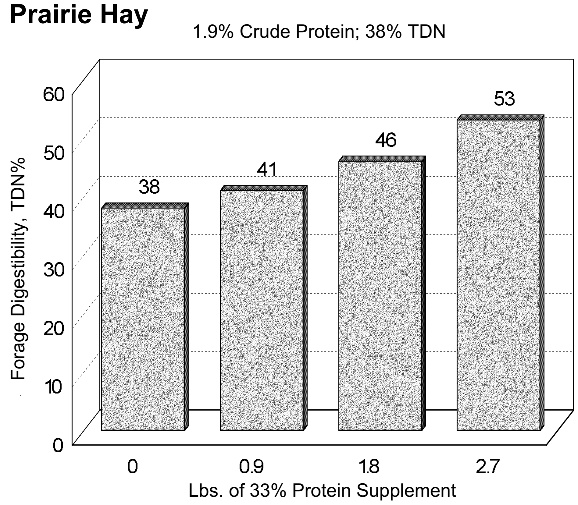
It is generally acknowledged that forage intake and digestibility of the forage will decrease with energy (grain) supplementation. However, sometimes the value of the grain to the animal offers a greater advantage than the disadvantage of lowering the forage value. Also, grain can be advantageous for stretching the forage supply. If forage quantity is insufficient, it is probably more economical to supplement with a combination protein/energy ration (20 to 25% protein; 40 to 50% grain) than a high protein ration. **Cattle will be unable to capitalize on the benefits of a high protein supplement when the forage supply is insufficient.** As a general rule, if utilization of available forage is less than 50%, use a high protein ration, but if forage utilization is

Figure 3. Forage Intake on Dormant Tallgrass Prairie Hay



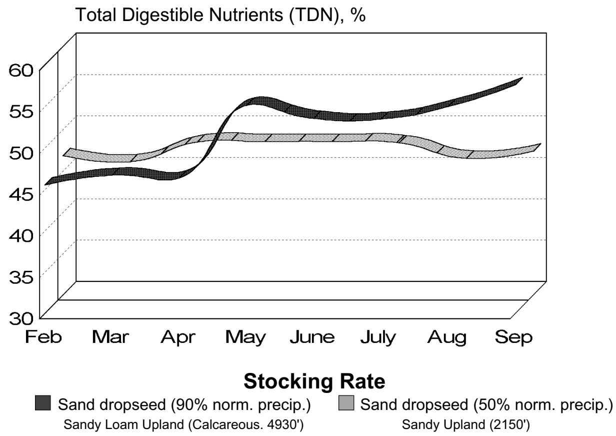
Stafford et. al., March 1996 *Journal of Animal Science*

Figure 4. Forage Digestibility on Dormant Tallgrass Prairie Hay



Stafford et. al., March 1996 *Journal of Animal Science*

Figure 5. Energy Content in Arizona During Drought



Arizona Strip Range Forage Quality Analysis Study (1996)

equal to or greater than 50%, use a protein/energy or energy supplement.

Figure 5 shows the energy content (TDN) of the same grass from the same sites as shown in Figure 2. The energy required for maintenance of lactating cattle is supplied by forage at around 56% TDN and for nonlactating around 52% TDN. At no time during 1996 was TDN above 49% for the low elevation range site with 50% of normal precipitation. Assuming forage availability was adequate, protein supplementation at the low elevation range site could possibly have increased both forage digestibility and intake to more optimal levels.

OTHER SUPPLEMENTS

In stressful situations in which cattle are losing weight, some benefits have been demonstrated by feeding supplements with approximately 40 to 60% of the protein being ruminally undegradable or bypass protein. Feedstuffs high in bypass protein include feather meal, blood meal, corn gluten meal, and fish meal. Due to palatability problems, rendered animal products are usually limited to 25 to 30% of the total supplement and are combined with grain products to increase palatability. Petersen et al. (1996) reported that weight loss has been reduced and conception rates increased in several experiments by feeding bypass protein. However, they reported that bypass protein supplementation only seems to be effective when animals are losing weight. The additional cost per ton for adding bypass protein is around $50 to $80.

Another form of supplementation during drought to increase harvestable forage is the hauling of water to seldom used areas of pastures. Granted, this is labor intensive and requires acreage which is easily accessible. However, in large pastures with few water developments, this can help in grazing distribution. In areas which are not excessively rugged, it is estimated that cattle will use 80% of the allowed harvestable forage up to 1 mile from a water source, but only 40% at 1.5 miles, and 20% at 2 miles from the water source. If there are areas in pastures exceeding 1 mile from water, then in effect you have a “forage bank” which can be utilized.

In order to avoid harming the range resource for subsequent years, maximum utilization of forage should not exceed 60% (Lacey, 1995). Exceptions are crested wheatgrass (Lacey, 1995) and annuals. Annuals should be grazed early and heavily during a drought year while they are still green and have greater nutritive values. Pastures should be rotated frequently and include longer rest periods due to reduced growth during drought. In some instances, it may be advantageous to open up pastures into larger pastures to allow for more selectivity by cattle. This will also help prevent cattle from “bogging down” in earthen water tanks with dropping water levels.

UREA SUPPLEMENTS

When forage quality is low and the TDN or energy value of forage is low (less than 45%), it may be risky to feed protein supplements with urea. However, research in this area is rather limited (Dr. Bob Cochran, Kansas State

University, personal communication). In some cases, urea toxicity may be more related to reduced forage availability than to forage quality. A rule which is widely quoted is that urea should constitute no more than 1/3 of the crude protein of a cow's diet. If this amount of urea in the diet is exceeded, there may be increased risk of urea toxicity and death. Symptoms of urea toxicity have been observed in cattle unaccustomed to urea in doses approximating .4 lbs of urea (equivalent to approximately 1.15 lbs. of crude protein supplied by urea) for a 1000 lb. cow (Radostits et al., 1994). If the protein supplement being fed contains 32% crude protein with 26.5% crude protein being derived from urea, the cow eating this supplement may be at risk if she consumes 4.34 lbs. of the urea based supplement (4.34 lbs. supplement • .265 crude protein for urea = 1.15 lbs. equivalent protein from urea or .40 lbs. urea). The crude protein:urea ratio can be determined by the feed tag, forage analysis, estimated forage intake from Table 2, disappearance of urea supplement, and the formula in the box right.

For example, forage analysis reveals that the forage is estimated to contain 5% crude protein and 45% TDN. Forage intake from Table 2 is estimated to be 1.7% of body weight or 17 lbs. for a 1000 lb. cow. Crude protein intake from forage is 17 • .05 or .85 lbs. The feed tag on the supplement contains 32% crude protein and 83% of this, or 26.5% crude protein, is from urea. The cattle are eating 4 lbs. of supplement a day, or .22 lbs. natural protein from supplement (4 • .055) and 1.06 lbs. protein from urea (4 • .265). The crude protein:urea ratio in this instance would be greater than the desired 3:1 ratio.

$$\frac{(.85 + .22 + 1.06)}{1.06} = \frac{2.00}{1.00}$$

If it is desired to continue feeding a urea based supplement in this case, then the amount of urea in the supplement needs to be reduced. If cattle were fed a urea based supplement with 20% crude protein of which 70% of the ration, or 14% crude protein, was from urea, then cattle could probably consume 4 lbs. of this supplement. If forage quality drops to 4% crude protein and 40% TDN, then cattle can only consume safely 2 lbs. of the 20% protein supplement.

$$\frac{[(12 \text{ lbs. forage} \cdot .04) + (2 \text{ lbs.} \cdot .06 \text{ natural protein}) + (2 \text{ lbs.} \cdot .14 \text{ urea})]}{(2 \text{ lbs.} \cdot .14 \text{ urea})} = \frac{3.14}{1.00}$$

The cutoff value for a urea based supplement with forage of 5% protein and 45% TDN (15% increase in forage consumption factored in for protein supplementation) is 2 lbs. of a 32% protein supplement with crude protein from urea = 26.5% and 4.5 lbs. for a 20% protein supplement with crude protein from urea = 14%.

One may be tempted to control the intake of liquid urea based supplements

$$\frac{(\text{lbs. protein from forage} + \text{lbs. natural protein in supplement} + \text{lbs. protein from urea})}{\text{lbs. protein from urea}}$$

Table 2. Forage Intake of Lactating Cattle at Different Forage Digestibilities

Forage Digestibility or TDN, %	Amount Required to Eat to Meet Maintenance Requirements, % of Body Weight	Amount Can Eat at the Forage Digestibility Listed, % of Body Weight[1]
43	3.2	1.2 to 1.3
45	3.1	1.7 to 2.0
50	2.8	1.9 to 2.1
55	2.6	1.7 to 2.1
58	2.4	1.9 to 2.5
60	2.3	2.0 to 2.5
62	2.3	2.3 to 2.8
64	2.2	2.6 to 3.2
Greater than 64		2.6 to 3.2

[1]Research from various sources including Kronberg et al., 1986; Kragner et al., 1986; Havstad and Doornbos, 1987; Sprinkle, 1992.

by locking the wheels on the feeder. However, research suggests that after 3 days of urea deletion from the diet, adaptation to urea based supplements is lost (Davis and Roberts, 1959). It is a much better practice to either eliminate completely the feeding of urea during drought or else significantly reduce the amount of urea in the supplement.

Signs of urea toxicity include rapid, labored breathing, muscle tremors, severe abdominal pain, frothing at the mouth and nose, irritability to sound and movement to the point of being aggressive, slight incoordination followed by severe incoordination and the inability to stand, weakness, bloat, and violent struggling and bellowing (Essig et. al, 1988; Radostits et al., 1994). Treatment, which is often too late, is oral administration of 4 liters of a 5% vinegar solution for a 1000 lb. cow (Davis and Roberts, 1959).

TOXIC PLANTS AND ADDITIONAL CAUTIONS

An additional caution for supplementation during drought is to avoid feeding supplements containing ionophores (trade names of Rumensin® or Bovatec®). Doing so can increase the probability of nitrate poisoning (Radostits et al., 1994). Nitrates can accumulate in forage during drought, and especially in the "green-up" following drought. Plants which are particularly susceptible to nitrate accumulation include kochia, lambsquarters, oat hay, Russian thistle (tumbleweed), sorghum, and filaree. Symptoms of nitrate poisoning are similar to other kinds of poisoning and include rapid pulse rate, labored breathing, and possibly muscle tremors and convulsions. Symptoms which are somewhat unique to nitrate poisoning include darkened membranes in the mouth, nose, and eyes and dark red to brown blood instead of bright red blood (Essig et. al, 1988). Treatment is accomplished with intravenous injection of 100 ml of a 4% solution of methylene blue / 1000 lbs. body weight (Essig et. al, 1988). According to Radostits et al. (1994), supplemental feeding of sodium tungstate (wolfram) under veterinary advisement can reduce the effects of nitrate poisoning in cattle grazing pastures with high levels of nitrate (greater than 1% nitrate nitrogen; Essig et al. 1988,).

During drought, one also needs to be alert to possibilities of toxic plant poisoning. Oftentimes, the greenest plants may be toxic (e.g., bracken fern, whorled milkweed). Forage production should be monitored closely and cattle should not be subjected to excessive stocking rates on the depressed forage base. Be aware of poisonous plants which exist in your pastures and carefully monitor the use of these plants by livestock.

CONCLUSION

It is important to plan ahead when supplementing cattle during drought. The most effective time to supplement cattle is before calving. It is almost impossible to put weight back on a cow during the first 45 to 60 days after calving. Nutrient requirements at this time are about 50% greater than in the last trimester of pregnancy. Producers should analyze forage for deficits in protein and TDN and supplement accordingly to maintain cow weight before calving (Sprinkle, 1996). Reproduction will drop sharply if cattle are thinner than a body condition score of 4 at breeding.

It is acknowledged that drastic effects can occur in a relatively short period of time during drought. In some cases, cattle may be in adequate body condition shortly before calving and lose weight rapidly as forage supplies and forage quality decline. Cattle should not be allowed to get below a body condition score of 3 in order to avoid increased susceptibility to diseases. Also, conception rates in cattle will possibly drop to 40 to 50% at body condition score 3 and to practically zero at body condition score 2. **If at all possible, a cow should not be allowed to become protein deficient during drought.** For every 1 lb. of protein deficiency, the loss of 6.7 lbs. of body weight would be required to supply this level of protein. Conversely, if the diet was deficient in energy (TDN), this would only require 1 lb. of body weight loss for each 1 lb. of TDN. If a cow was deficient in TDN by 1.5 lbs. per day and initial body condition score was 4, the cow could lose 1.5 lbs. a day for 53 days and drop to a final body condition score of 3.

In the worse case scenario, some cattle should be sold to stretch forage supplies while also feeding supplement to remaining cows to maintain desirable body condition during breeding. Heavier milking and larger cattle would be good candidates for culling, because their maintenance requirements will be much larger. Since 2-year-old cows will require more supplementation and be more difficult to rebreed, you may want to consider selling these cows as well. Above all else, use pregnancy testing as a tool to reduce herd size and preserve a reasonable calf crop the following year. Income from sale of cattle during drought may be eligible for income deferment for 1 year if in an area that has been declared a drought disaster area. If extreme destocking is expected, early weaning of calves should be considered. Nonlactating cattle will eat only 70% as much as lactating cattle, so this will spare the forage base somewhat during drought.

In conclusion, drought usually requires some type of supplementation to avoid extreme weight loss in cattle. If cattle are allowed to become too thin, conception rates may decrease markedly. By obtaining forage or fecal samples and analyzing for protein and TDN, supplements can be matched to drought conditions.

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Arizona Cooperative Extension

Issued in furtherance of Cooperative Extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, James Christenson, Director, Cooperative Extension, College of Agriculture and Life Sciences, The University of Arizona.

MANAGING NUTRITIONAL CHALLENGES TO REPRODUCTION

Jim Sprinkle[1]

INTRODUCTION

Nutritional challenges placed upon the lactating cow can be extreme in Arizona. Among these are the extra nutritional requirements caused by lactation. Figure 1 illustrates the weight loss which usually occurs in a lactating cow during the first 45 to 60 days of lactation. At the period of time at which the cow has lost the most weight, producers are trying to rebreed her in order to maintain a yearly calving interval. It is usually not possible to entirely prevent weight loss during early lactation with range cattle. A better strategy is to plan ahead to allow for weight loss by building or maintaining body fat stores before calving.

Another challenge with Arizona ranching operations is the reduction in forage quality with mature forage. Rainfall often occurs in a biannual pattern and forage quality before the monsoon rains and in late winter can be low. As forage matures, protein, total digestible nutrients (TDN), and phosphorus often decline below levels considered adequate. In addition, certain trace minerals may be deficient year round. It is a good practice to analyze dormant forage to determine protein, TDN, and phosphorus content. You can then match cow supplementation to the forage resource (See *Matching Forage Resources with Cow Herd Supplementation*). It is also a good practice to analyze forage for trace mineral status over two or three years to establish baseline data for your ranch. Trace minerals in Arizona which may be of concern are selenium, copper, zinc, sulfur, and molybdenum.

There are several options one can take to help meet the nutritional challenges placed upon cows by lactation and the environment. Some of the most prominent are listed below and shall be explained more fully:

1. Create a “fat storage cushion” for lactating cows by maintaining body condition score (1 to 9, 9 = fattest; Richards et al., 1986) at 5 or greater before calving. As part of this strategy, utilize protein supplements for low quality forage to increase forage intake and digestibility.

2. If in spite of your best efforts, cattle are thin at breeding time, attempt to “flush” cattle with your best quality pasture and/or by supplementation. If combined with short-term calf removal, flushing will be more effective.

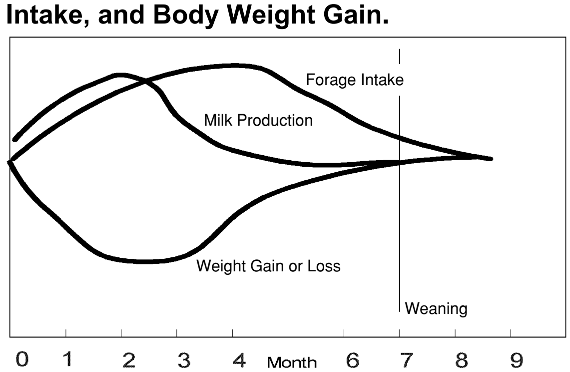
3. Match calving season to the forage curve.

4. Genetically match the cow to the environment.

OPTION 1: MAINTAINING BODY CONDITION AT 5 BEFORE CALVING

As shown in Figure 1, it is an advantage to allow cattle to have fat reserves they can mobilize during early lactation. Research has shown that reproduction will suffer if cows are allowed to become too thin at calving, especially with

Figure 1. Milk Production, Forage Intake, and Body Weight Gain.



After Coppock, 1985 (adjusted for beef animal)

Table 1. Pregnancy % by Body Condition Score

Body Condition at Calving	Day 40 of Breeding Season	Day 60 of Breeding Season
4	43 ± 5	56 ± 5
5	65 ± 4	80 ± 4
6	90 ± 9	96 ± 8

Spitzer et al. May 1995. Journal of Animal Science

younger cows. Table 1 illustrates the effects of different fat reserves with two-year-old cattle.

One problem faced in attempting to maintain body condition at 5 before calving is that during the last trimester of pregnancy forage quality can be quite low. As forage quality decreases, lignin and other more slowly digestible components of forage increase. The result of these changes in forage quality is that forage remains longer in the rumen before exit, reducing forage intake. Thus, the cow may be unable to eat enough forage to maintain body weight (Figure 2).

When forage contains less than 6.25% protein, protein supplementation can be effective. When additional protein is made available in the rumen, this increases the synthesis of new microorganisms in the rumen which are ultimately responsible for fiber digestion. This is illustrated in Figures 3 and 4 where forage intake and forage digestibility were increased by protein supplementation for cattle eating poor quality (2% crude protein) prairie hay. For Arizona, data collected by Cooperative Extension workers has shown that the crude protein of blue grama native range during the winter months of December to February varied between 1.58 and 7.55%.

In the above scenario, nonlactating cattle fed 2.7 lbs. of protein supplement should maintain body weight as the energy requirement for nonlactating cattle is around 52% TDN. Cattle fed less protein would probably lose weight; the greatest weight loss occurring with no protein supplement. Greater conception rates would be expected for the cattle fed 2.7 lbs. of protein supplement. If management will allow it, it is cost effective to separate thin cows from fat cows before calving and supplement protein to thin cows according to forage deficits. Research in West Texas (Huston et al., 1999) has indicated that protein supplements can be fed as infrequently as once a week without detrimental effect. If energy supplements are fed (e.g., corn, milo), they need to be fed daily.

Conception rate will be improved by keeping cattle in good body condition prior to calving. Forage intake and digestability can usually be improved with late season dormant forage through the use of protein supplements. Cost effective supplementation can be integrated into prepartum nutritional management programs by analyzing forage for nutritional deficiencies and then supplementing accordingly.

OPTION 2: FLUSHING AFTER CALVING AND SHORT TERM CALF REMOVAL

Table 2 shows the effect of flushing thin cattle with a high energy ration after calving. Cattle in this study (Richards et al., 1986) were fed different levels of energy after calving. Two of the groups were limit-fed a similar corn silage diet after calving to lose 1.00 to 1.50 lbs. of body weight per day. Two weeks before the breeding season started, one of these two groups was then flushed with 9 to 13 lbs. of corn and corn silage fed to appetite. The flushing ration was continued throughout the first 30 days of the breeding season. Both groups had calves removed from cow for 48 hours two days prior to the initiation of the breeding season. Flushing and calf removal had little effect upon cattle that were already in good condition at calving but increased conception markedly for thin cattle. Although it may be difficult to provide supplementation to cattle in extensive range operations, this principle can be applied by using excellent quality pastures after calving. For instance, if filaree was in abundance in a particular pasture, it could be used to help flush cattle before breeding.

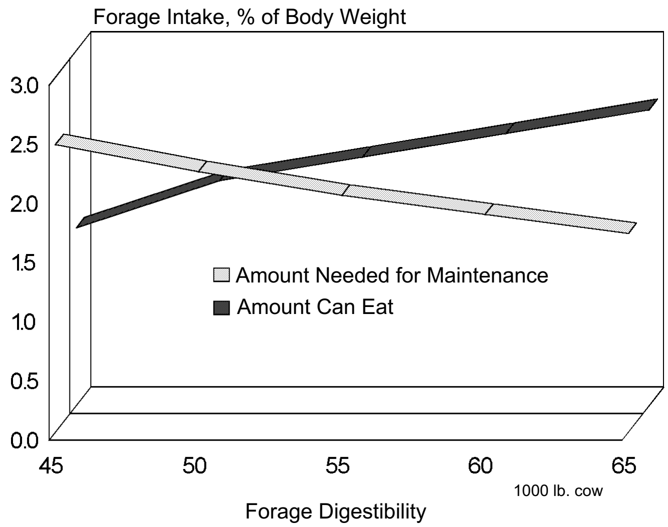
Another tool that can be used in combination with flushng is short term calf removal (Smith et al., 1979; Richards et al., 1986). If cattle are being worked for spring branding, calves could be separated from cows for 36 to 48 hours and not allowed to nurse. Research has shown this to be effective in increasing estrus with thin cows (body condition score 3 to 4; Nix et al., 1981). Researchers in Texas have shown that short term calf removal can be particularly effective with Brahman cross cattle which sometimes have long periods of time before the first estrus postpartum (Nix et al., 1981). *A note of caution:* short term calf removal with cows having a body condition score less than 4 may not be effective in increasing conception rate unless cattle are provided with some type of nutritional supplement as well (L. R. Sprott, Texas A & M University, personal communication). Additional research in Australia has suggested that lactating Brahman and Brahman cross cattle will preferentially shunt nutrients from supplements into milk for the calf (Hunter, 1991). Therefore, it may be necessary to combine short term calf removal with flushing in order to elicit a positive response for Brahman crosses in any supplementation done after calving. Researchers in Texas (Randel and Welker, 1980) compared Brahman x Hereford first-calf heifers fed at 125% of daily energy requirements in a drylot and either exposed to normal calf suckling or once-daily suckling. At 90 days postcalving, 100% of once-daily suckled heifers had returned to estrus compared to only 35.3% of normal-suckled heifers.

Table 2. Body Condition and Feeding Level (Pregnant 1 breeding)

	Body Condition	
Feeding Level[1]	**4 or less**	**5 or greater**
Low + Flushing	75%	70%
Low	54%	70%

[1] The low energy diet consisted of a corn silage diet fed at approximately 62% of daily requirements (if cattle weighed 1000 lbs. and were milking 12 lbs. per day) from calving throughout the first 30 days of breeding season. Cow that were flushed received the same diet until two weeks prior to the breeding season. At this time, cows of the flushing diet received a diet that provided approximately 1.5 times the daily energy requirement. The flushing diet was continued throughout the first 30 days of breeding. Both groups had calves removed from suckling for 48 hours at the initiation of breeding season.

Figure 2. Forage Intake of a Nonlactating Range Cow

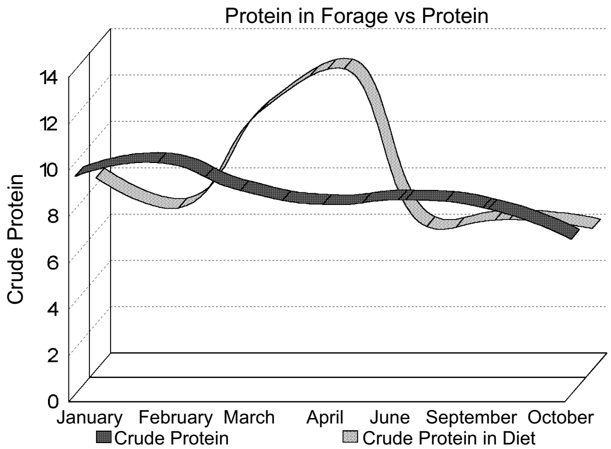


OPTION 3: MATCH CALVING SEASON TO FORAGE CURVE

From Figure 1, it would make sense both physiologically and economically to match the calving season to times in which forage quality is at its peak. In fact, Deseret Ranches of Woodruff, Utah attributes moving calving forward to match the forage curve as one of the key ingredients in reducing cow costs and improving fertility (Simonds, 1991).

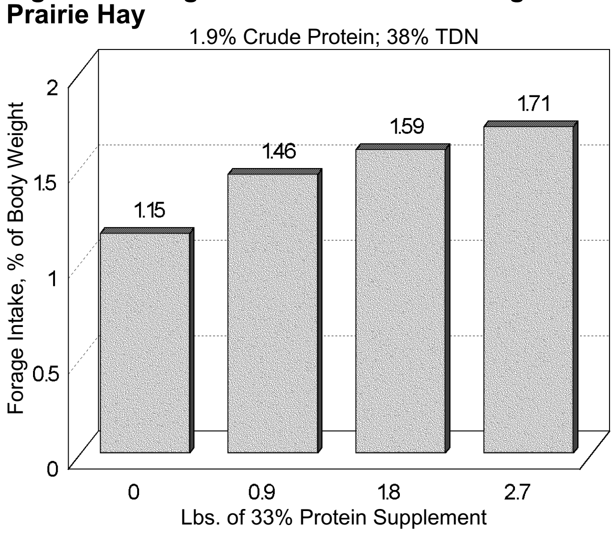
Figure 3 illustrates crude protein content of forage produced and consumed by

Figure 3. Mohave County Ranch



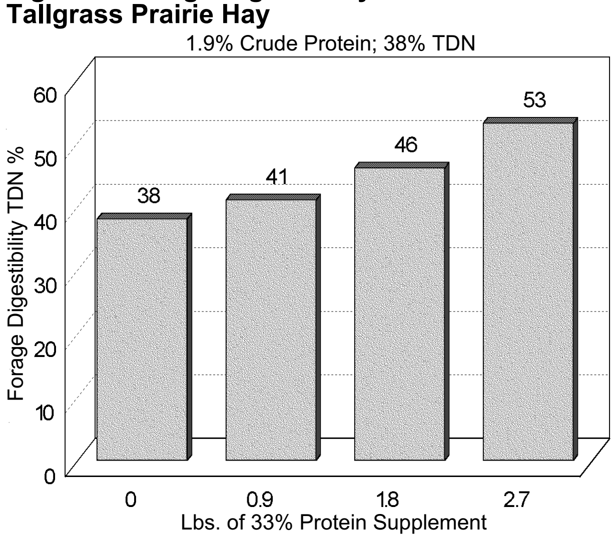
Chaparral to Grassland (4800 to 5500 ft.)

Figure 4. Forage Intake on Dormant Tallgrass Prairie Hay



Stafford et al., March 1996 *Journal of Animal Science*

Figure 5. Forage Digestibility on Dormant Tallgrass Prairie Hay



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cattle on a Mohave County Ranch. The dark line indicates the crude protein requirements at different times of the year with estimated forage intakes at these times. Composition of the diet was determined on this chaparral-grassland ranch (4800 to 5500 ft.) by micro histological analyses of fecal samples. Crude protein of the diet chosen (light-colored line) was then determined by lab analyses of forage samples. The diet chosen during January and February was 50 and 60% *turbinella* oak, respectively. In April, the diet consisted of 30% filaree and 30% ceanothus. Forage intake and fiber and protein digestibility during January and February would have been reduced due to the negative effects of tannins present in turbinella oak. Crude protein content of filaree was very high in April (22.1%) and had a major effect on crude protein of the diet consumed. Looking at Figure 5, it would appear that the ideal time for calving would be in early March. This would allow for nutrition to be at its peak during the 60 days preceding breeding. There are also two times of the year in which management decisions would need to be made. In January to February, it would appear that protein supplementation would be appropriate to prevent accelerated weight loss before calving. During June breeding season, supplementation decisions would be based upon body condition. If cows had gained sufficient weight during March and April, they would be able to coast through June without any supplementation. However, if cows were slipping in body condition in May or early June, supplementation would be advisable. Each ranch will be a little different in its forage curve and it is a good idea to analyze forage at different times of the year to gain an understanding of the forage curve for that ranch. Matching the calving season to the forage curve should improve cow nutrition and increase the number and size of calves weaned.

OPTION 4: MATCH THE COW TO THE ENVIRONMENT

Cattle of intermediate size (1000 to 1200 lbs.) and milk production (18 lbs. or less peak milk production per day) appear to work best in more arid environments. Low desert chapparal rangelands with limited herbaceous forage may require the use of small framed cattle (850 to 900 lbs.) with low milk production (8 to 12 lbs. peak milk production). Modest increases in cow size are accommodated more readily than are increases in milk production.

If forage availability is not a problem, cattle with greater milk production can increase forage intake to meet increased energy demands due to milk production. In areas with greater rainfall (e.g., Midwest) this can be easily accomplished. In more arid areas of the West, cattle with greater milk production are often at a disadvantage. Each additional lb. of milk production (butter-fat content = 4.03%) would require an additional .52 lbs. of forage intake if forage TDN was equal to 56%. By increasing peak milk production by 2 lbs. per day, calf weaning weights could be increased by 26 lbs. at 205 days while also increasing forage demand of the cow by 1.04 lbs. per day. If the cow was unable to satisfy this demand due to constraints placed upon her by lesser forage quality and quantity, weight loss would occur.

Table 3 compares a hypothetical cow with peak milk production of 19 lbs. to one with peak milk production of 21 lbs. Forage TDN ranged from 50 to 62% in this example and forage intake was adjusted downward in December, January, and February. In this fictitious example, cattle were supplemented with adequate protein in January and February to maintain weight as shown in the last column. Cattle in this example had a frame score of 4 with a weight of 1103 lbs. at a body condition score of 5 (Fox et al., 1988). The average weight difference between

Table 3. Comparison of Increasing Milk Production

Average Cow with 19 lb. Peak Milk Production					
Month	Forage TDN%	Est' d Forage Intake, lbs.	Milk Prod., lbs.	Cow Wt. w/o suppl.	Cow Wt. with suppl. Jan. & Feb.
Jan.	50	19.9	0	1045	1103
Feb.	52	18.8	0	988	1103
Mar.	59	26.5	18	943	1059
Apr.	60	28.7	19	940	1056
May	62	30.9	17	961	1076
June	58	26.5	15	937	1052
July	60	28.7	11	955	1071
Aug.	62	27.6	8	981	1097
Sept.	60	24.3	6	990	1105
Oct.	58	23.2	0	1017	1132
Nov.	55	21.0	0	1027	1143
Dec.	52	19.9	0	982	1097
Cow with 21 lb. Peak Milk Production					
Jan.	50	19.9	0	1045	1103
Feb.	52	18.8	0	988	1103
Mar.	59	26.5	20	924	1040
Apr.	60	28.7	21	903	1019
May	62	30.9	18	922	1037
June	58	26.5	16	888	1004
July	60	28.7	13	902	1018
Aug.	62	27.6	8	928	1043
Sept.	60	24.3	7	934	1050
Oct.	58	23.2	0	961	1077
Nov.	55	21.0	0	972	1087
Dec.	52	19.9	0	926	1042

body condition scores (1 to 9) was 86 lbs. The cow with the lower milk production achieved a body condition score of 5 at the end of the year with supplementation in January and February. The cow with increased milk production had less body condition at the end of the year, being approximately 4.25 at 1042 lbs. At breeding time in June, the cow with greater milk production would have a body condition score of 3.7 as compared to 4.4 for the other cow. If we assume a modest decrease in conception from 85 to 77% for greater milk production, there would be a net loss of $1269.80 for 100 cows with the following parameters: 477 lb. weaning weight for lesser milk production, 503 lb. weaning weight for greater milk production, 70¢ per lb. calves.

(477 lbs. • .85 • .70 • 100) - (503 lbs. • .77 • .70 • 100) = $ 1269.80

In Table 3, cattle with greater milk production were not adjusted upwards for greater forage intake to show the effects of greater milk production in a more limiting environment. In periods of time with better forage quality and adequate forage availability, cattle with greater milk production can have greater forage intake. Therefore, weight loss could be somewhat less than that projected in Table 3. However, the extra milk production would result in greater weight loss for these cattle and most likely would result in lower body condition at the end of the year. Ultimately, it is expected that the greater milk production cattle would wean fewer lbs. of calf per cow exposed.

Cattle can be selected to match Arizona's environment. Data is available from the Meat Animal Research Center of Clay Center, Nebraska to compare breeds for different traits (http://www.ansi.okstate.edu/breeds/research/marccomp.htm). Selection within breeds can also be practiced by using EPDs (Expected Progeny Differences) as a selection criteria (Sprinkle, 1996b) for targeting production goals. Important traits to set selection criteria for to achieve optimum reproduction in Arizona could include fleshing ability, mature size, milk production, and longevity. If cattle are not properly matched to our Arizona environment, an additional handicap is placed on the cowherd during years with unfavorable precipitation. On average, this occurs in Arizona four years out of ten (Holochek et al., 1998).

CONCLUSION

Maintaining body condition at a score of 5 at calving should help enhance conception rates for Arizona range cattle. A key component of management is to have a knowledge of forage quality at different times of the year. Supplementation and calving season can then be matched to the forage resource. Finally, matching the cow to the environment can help overcome nutritional challenges to reproduction.

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FROM:

Arizona Ranchers' Management Guide
Russell Tronstad, George Ruyle, and Jim Sprinkle, Editors.
Arizona Cooperative Extension

HEIFER DEVELOPMENT ON RANGELAND

Jim Sprinkle[1]

INTRODUCTION

Heifer development is one of the three largest expenses for beef cattle operations when the opportunity cost for retaining heifers is factored in. You can purchase replacement heifers of breeding size or develop your own heifers in the feedlot, farm dry lot, irrigated pasture, or on range. In some areas of the country, companies which develop ranchers' heifers for a fee are available as well. The option you choose depends upon the timetable desired for heifer replacements and the economics of each option for a particular operation. Unless hampered by a lack of good quality, inexpensive feed, there is usually a cost advantage in developing heifers from the herd instead of purchasing them. An additional advantage is that you have knowledge of the performance of selected females' dams and the ability to more closely match replacement females to the particular environment. Inexpensive computer programs or worksheets are available ($1 for publication, $20 for computer program, Willett and Nelson, 1992) which allow you to calculate the costs of buying vs. retaining replacement heifers.

It has been well documented that in order to achieve puberty, heifers need to weigh around 60 to 65% of mature weight at breeding time. For British breeds this is around 650 to 700 lbs. at around 14 to 15 months, and for Continental breeds, 750 to 800 lbs. at the same age. (There are exceptions to this rule; a small percentage of heifers will be pubertal while still nursing). Achieving this level of weight gain following weaning is rather easy in the feedlot, dry lot, and possibly irrigated pasture, but can be rather difficult on rangelands with poor quality winter forage. The disadvantage with feedlot development is cost. One Arizona breeder calculated that when he utilized feedlot development of replacement heifers, the cost per pregnancy (90% conception rate) was over $160 compared to a little over $60 per pregnancy for heifer development on pasture with supplement (85% conception rate).

RANGE LIMITATIONS

The difficulty in developing replacement heifers on low quality feed is illustrated by Figure 1. The lower portion of each bar represents the amount of forage a 500 lb. heifer would have to eat of a given forage quality in order to maintain body weight. The shaded portion of each bar represents the amount of additional forage the heifer would have to eat in order to gain .5 lbs./day, a reasonable expectation for weight gain on winter range. The solid line represents the amount of forage a heifer can actually eat for that particular forage quality. With lower quality forages, forage intake could possibly be increased 10 to 15% by protein supplementation. However, from this diagram it can be seen that the heifer may not be able to gain any weight until forage quality approaches 56% digestibility. What often happens with heifers

Figure 1. Heifer Development on Rangeland

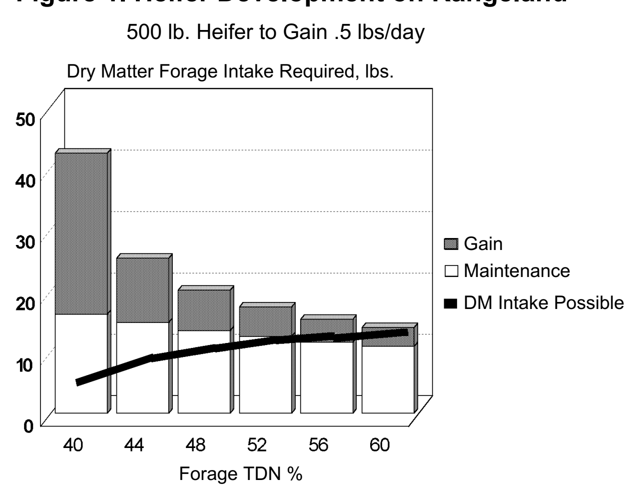

Table 1. Forage Quality and Heifer Weight Gains[a]

TDN, %[b]	ME,Mcal/lb. forage[b]	Neg,Mcal/lb. forage[b]	Est. forage intake lbs./day[c]	Est. weight loss or gain lbs./day
40	.66	.03	6.0	-4.2
42	.69	.07	6.0	-4.1
44	.72	.10	7.0	-3.5
46	.75	.13	8.5	-2.7
48	.79	.16	9.5	-2.0
50	.82	.19	9.5	-1.8
52	.85	.22	10.0	-1.3
54	.89	.25	10.0	-1.2
56	.92	.28	11.0	-0.3
58	.95	.31	11.0	-0.1
60	.98	.33	11.5	+.10[d]

[a] 500 lb. medium frame heifer with no supplementation, approximate Mcal ME required for maintenance=10.64/day.

[b] TDN=total digestible nutrients, ME=metabolizable energy, Mcal=megacalories (1,000,000 calories), Ne_g=net energy for gain. Each 1 lb. of gain requires 2.1 Mcal of Ne_g. Ne_g is energy available for gain *after* satisfying maintenance demands.

[c] Estimates of forage intake at different forage digestibilities are best guesses based upon the following research: Kronberg et al., 1986; Wagner et al., 1986; Havstad and Doornbos, 1987; and Sprinkle, 1992.

[d] Gain will probably be greater due to greater forage intake at this forage quality. If a heifer eats 13 lbs. of forage/day, average daily gain will be approximately .4 lbs./day. High growth potential cattle may exceed this gain projection.

Table 2. Heifer Development on the R100

San Carlos Apache Tribe			
	Supplement, lbs./day		
	0	4.2	5.6
Weaning Weight (10-6), lbs.	396	396	400
ADG, lbs.	-0.21	0.43	0.66
Ending Weight (3-23), lbs.	361	468	513
% Calving	0	31	54
% Calves Weaned of Total		20	36
% Calves Weaned of Those Calving		65	66

Study by University of Arizona, Ray et al.,1993, AZ Ranchers' Management Guide

developed on native range is that replacement heifers will often coast through the winter with no weight gain or a slight weight loss and then start gaining weight following "green up." This makes it difficult to achieve weight gains needed to get heifers cycling for early breeding. Table 1 presents some rough projections of anticipated weight gains with different forage qualities. From this, it should be quite clear that heifer development on rangeland usually requires some type of supplementation in addition to forage consumption.

Tables 2 and 3 contain data for two different studies relating to heifer development. Table 2 compares heifers at San Carlos (Ray et al., 1993) fed either 0, 4.2, or 5.6 lbs./day of a protein-energy supplement with 65% milo and 25% cottonseed meal (24% total crude protein). Heifers weighed around 400 lbs. at weaning and heifers gained -.21, .43, and .66 lbs./day for 0, 4.2, and 5.6 lbs. of supplement. Beginning in May, heifers were exposed to bulls for 60 days. Although the authors did not report weights at breeding, it is assumed that the weights were less than ideal target weights. None of the control heifers conceived, compared to 31% and 54% for the low and high feeding levels. However, due to small size of heifers at calving, approximately one-third of the heifers lost calves at or shortly after calving.

Table 3 reports the findings of Lemenager et al. (1980). Cattle in this study were fed poor quality fescue hay (9%, 8.5%, and 8.8% crude protein for trials 1, 2, and 3, respectively; TDN not determined). Heifers in this study appeared to be deficient in both protein and energy. When the control heifers had 1.8 lbs. of protein supplement added to their diet, they went from a small weight loss to an average daily gain of around .5 lbs. Addition of protein also nearly doubled weight gains for animals fed corn. If control heifers in this study had been able to eat 2% of their body weight daily, they

Table 3. Heifer Development with Different Levels of Corn

		Supplemental Corn Fed		
	Base Ration	0 Lbs.	2.7 Lbs.	5.4 Lbs.
		Starting Wt., lbs.		
Trial 1 (113 d)	fescue hay (poor quality)	516	516	510
Trial 2 (153 d)	fescue hay (poor quality)	494	493	475
Trial 3 (150 d)	fescue hay + 1.8 lbs. protein supplement (32%)	481	500	499
		Winter ADG, lbs.		
Trial 1 (113 d)	fescue hay (poor quality)	-0.18	0.35	0.62
Trial 2 (153 d)	fescue hay (poor quality)	-0.09	0.29	0.53
Trial 3 (150 d)	fescue hay + 1.8 lbs. protein supplement (32%)	0.49	0.79	1.15

Lemenager et al., 1980. *Journal of Animal Science*

would have had nearly adequate crude protein intake during trial 1, (although not all the protein may have been available) and would have been slightly deficient in crude protein in the other trials if no additional protein were supplied. In reality, forage intake during trials 1 and 2 may have been less than 2% of body weight. The addition of supplemental protein during trial 3 could possibly have increased both digestibility and forage intake. Heifers in this study were placed on good quality pasture following the study and pasture bred for 60 days. The heifers receiving lesser amounts of supplement during the winter exhibited compensatory gain while on pasture. Weight gains on pasture averaged over all years were 1.7, 1.5, and 1.3 lbs. for heifers fed 0, 2.7, and 5.4 lbs. of corn during the winter, respectively. Pooled data over all three years had 69%, 74%, and 84% conception for the heifers fed 0, 2.7, and 5.4 lbs. of corn per day.

UNIVERSITY OF NEVADA STRATEGY

Heifers in the Lemenager et al. (1980) study performed better than the San Carlos study (Ray et al., 1993) due to being larger at the beginning of the feeding period. Heifers need to reach an age and weight threshold to initiate puberty (Table 4). Chronic feed restriction will prevent or delay puberty in heifers. The University of Nevada, Reno (Torell et al., 1993) has developed a 4 point plan for heifer development with smaller framed range cattle.

1) Meet target weight of 600 lbs. at breeding time.
2) Have heifers at a body condition score of 5 or greater at breeding.
3) Have heifers at a reproductive tract score (LeFever and Odde, 1986) of 3 or greater at breeding. (No immature uterine tracts with less than 3/4" diameter uterine horns and no tone).
4) To ensure less calving difficulty, make sure pelvic areas exceed 150 sq. cm at 12 months of age.

Following these guidelines will improve reproductive success with replacement heifers. It is also important to avoid nutritionally stressing replacement heifers after breeding and prior to calving. This will reduce growth in the pelvic opening and nullify attempts to manage for less calving difficulty.

FEEDING STRATEGY

Achieving acceptable weight gains on winter range in order to reach target

Table 4. Puberty Traits

Breed	13.5 Mos., % pubertal	Adjusted age,[a] days	Adjusted Wt.,[a] lbs.
Red Poll	88.6	359	650
Hereford	39.9	411	695
Angus	57.4	393	697
Limousin	44.0	408	743
Braunvieh	94.2	350	732
Pinzgauer	92.1	360	739
Gelbvieh	92.9	353	745
Simmental	86.8	363	758
Charolais	60.6	391	814
Composite, 75% Continental	85.8	366	765
Composite, 50% Continental	89.3	361	738
Composite, 75% British	84.0	368	723

[a]Adjusted to 100% puberty basis.
Gregory et al., 1995. USDA-MARC, Clay Center, Nebraska

weights for puberty can be a challenge. If weaned heifers weigh from 450 to 500 lbs. in late October and the target weight for breeding in June is 650 lbs., then heifers need to gain from .7 to 1.0 lbs. per day. Achieving this level of gain will enhance fertility by allowing heifers to have at least one heat cycle before the breeding season starts.

Based upon computer modeling and limited research data available for Arizona rangelands, weight gains that can be expected on moderate quality winter range (50% TDN, 5% crude protein) in conjunction with 4.5 to 5.0 lbs. of supplement (protein or protein/energy) per day would be around .5 lbs. of weight gain per day. If the supplement costs $180 per ton, daily cost of the supplement alone would be from $0.41 to $0.45 per head per day.

Replacement heifers can be placed in a dry lot during the time period when winter forage quality is poor and achieve weight gains of 1 lb. per day on a high roughage diet (less than 20% grain) at a cost of $0.72 to $0.82 per head per day (based upon feed costs of $100 per ton or good quality alfalfa hay and $10 per cwt. for grain). Depending upon the genetics of your herd and the quality of your hay, you may be able to achieve this rate of gain with little or no grain. If you desire to increase average daily gain to 1.5 lbs. per day, this would require an additional 1.7 lbs. of corn, 2.3 lbs. of cottonseed meal, or 5.3 lbs. of good quality alfalfa hay. This is in addition to the 14.4 lbs. of feed previously allocated for a 600 lb. heifer fed in the dry lot.

An ideal strategy for meeting target breeding weights when developing heifers on rangeland could be as follows. After calves have the “bawl” out, turn them into excellent quality riparian pastures (rested all year for winter grazing) or on hay stubble for about a month (November) or until forage utilization goals are reached. When forage quality declines significantly on rangeland (approximately November 1 to February 15 for low elevation or November 1 to March 15 for high elevation range sites), feed heifers in a dry lot with excellent quality hay. If winter precipitation is favorable and annual grasses are growing well, turn the heifers out after the dry lot feeding period to utilize the cheap range forage. Heifers will exhibit compensatory gain when placed on excellent quality forage. If average daily gain on spring pasture is 1.2 lbs. per day for 75 days, then weight gains in early winter for 450 to 500 lb. British cross replacements will only need to be from .5 to .9 lbs. per day. By monitoring weight gains regularly and by looking at forage quality and quantity closely, you will be able to decide when grazing winter range is appropriate and when additional feed is required.

Since you will probably have to supplement your replacement heifers to achieve desired weight gains before breeding, you may want to consider adding an ionophore (Rumensin® or

Bovatec®) to the grain, protein, or liquid molasses supplement. In a recent review in the Oct. 21, 1996 issue of *Feedstuffs,* Huntington reported that grazing ruminant animals supplemented with ionophores had increased nitrogen digestibility and 6% greater weight gains than controls. These findings were determined on more than 2,000 cattle in over 30 studies.

An additional advantage which has been observed by feeding Rumensin® to replacement heifers may be inducement of puberty at an earlier age (Lalman, et al., 1993).

CONCLUSION

When considering a breeding program, you may wish to use breed combinations to improve puberty traits. Table 4 shows that there is a great deal of variation in puberty traits for the percentage of females showing estrus at 13.5 months. Dual purpose breeds of cattle generally express puberty earlier than most other breeds except Red Poll. You may desire to include a percentage of one of the earlier puberty breeds in your breeding herd if you need to improve conception for yearling heifers.

When replacement heifers are selected at weaning, weigh the heifers and then determine how much weight heifers will need to gain by breeding time (see Table 4). Next, count the number of days until the start of breeding time and calculate average daily gain needed. Target weights for heifers should be achieved at least one heat cycle (21 days) prior to the start of breeding season. It is to your advantage to select heavier heifers (at least 450 to 500 lbs.) so that the desired weight gain can be achieved without excessive cost. Tailor the heifer development program so that the feeding program will accommodate the desired weight gains without allowing heifers to get too fat. If heifers gain weight too rapidly, it will increase feed costs and decrease lifetime productivity due to excessive fat deposition in the udder. Feeding tables are available from the National Research Council or your local Cooperative Extension office which will predict the nutrient requirements needed for your heifer development feeding program.

I would recommend that if you develop breeding heifers on rangeland that you analyze forage for protein and TDN and supplement accordingly. Supplement to achieve desired weight gain according to “Matching Forage Resources with Cow Herd Supplementation,” in this Guide. Do not let heifers become deficient in protein, or weight loss will accelerate. Keep mineral supplements out to heifers according to mineral deficiencies in your area by season of the year. Certain areas of Arizona are deficient in selenium, copper, or zinc, and most areas will be deficient in phosphorus when forage is dormant. If you need help in balancing rations for your forage base, contact your local extension office.

Though the Nevada system of heifer development works for the most part, scoring reproductive tracts has limited value for Arizona. However, having heifers in good body condition and selecting for adequate pelvic area are good management practices to follow. The bottom line is to achieve target breeding weights and ages in replacement heifers at breeding time (Table 4). Combined with genetic selection for puberty and matching forage deficits to nutritional supplements, heifer development on rangelands can be made more cost effective.

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