Blended Total Rations for Lactating Cows

Charlie J. Jarrett, *Ph.D.*
Extension Dairy Science Department
University of Georgia
Athens, Georgia

Researchers have been busy for many years trying to find the secrets that nature has locked up in the rumen and digestive track of the dairy cow. Their efforts have been to find out just what happens in there and what makes it happen. Many findings have been made and many secrets have been unlocked. However, I am sure that there are many undiscovered things taking place. The objective of this type of research is to find out what the requirements in terms of feed nutrients are for top milk production and proper maintenance of the cow. I feel confident that many of these requirements are known.

Ruminants were created to utilize forage. This, coupled with the fact that our agronomic condition is such that forage will be grown in large quantities, means that forage will make up a major portion of the feed supply for dairy cattle.

Concentrated research in forage evaluation, as a feedstuff, is now nearing its first century mark. The literature is almost unbelievable in scope and equally unbelievable in its lack of uniformity and real usefulness. The lack of uniformity in forage quality is brought about by several factors, such as different species, stage of maturity at harvest, and weather conditions. A farmer may start out to produce excellent forage, but due to weather conditions, it turns out to be poor quality. Nevertheless, he is still saddled with getting the most out of it that he can.

With such a large portion of the ration coming from forage, it is impossible to properly balance a ration without knowing the quality of the forage. For this reason most states and most feed companies have initiated programs for determining the relative feeding value of individual lots of hay and silage. These programs have several names. The most common being, "Forage Testing."

The Georgia Cooperative Extension Service initiated such a program in 1961. The samples are mailed to the lab. There they are tested for moisture, crude protein, crude fiber, and all of the major mineral elements as well as most of the trace elements. These results are forwarded to The Extension Dairy Science Department at the College in Athens. We calculate the energy value based on formulas developed at Auburn University. These formulas were based on actual feeding trials. This information is then used to structure a feeding program for the dairy farmer.

With our herds becoming larger, and with the advent of extensive mechanization, it is evident that we need a new feeding system. When we were dealing with small herds of 20 to 50 cows, each cow could be handled as an individual. If one of the feeding systems was used to outline a feeding program for the herd, any deficiency in the program could be corrected on an individual cow basis, simply by the feeder observing the response and needs of each cow and adding a little more to some cows and taking away from others. In larger herds handled with a minimum of individual attention, this "eye of the master" type feeding is no longer possible.

In recent years research workers have given considerable attention to this problem. Some of the first theories along this line were put forward by Blaxter of England several years ago. He took into account three things: 1) The efficiency with which a diet is utilized increases with the energy density, or the concentration of energy per unit weight of the ration, 2) The metabolizable energy value of a ration is corrected for differences in plane of nutrition, 3) The utilization of a ration is influenced by the type of performance required by the animal.

The data in Figure 2 illustrates Blaxter's preferred values for the efficiencies of utilization of metabolizable energy for maintenance, body gain, and milk production. Beginning with a low concentration of metabolizable energy (1.6 Mcal/kg.) typical of a ration consisting of a low quality forage and proceeding to a very high concentration of 3.4 Mcal/kg. (typical of an all concentrate ration). The general effect of ration energy concentration can be seen. The concentration of energy in the ration has little real effect on the use of the ration for maintenance. This is in keeping with farm experience that lower quality feed can be used for maintenance so long as intake is sufficient and no major nutrient is missing. The overall relationship between energy concentration and milk production is curvilinear. Increasing the concentration from 1.6 Mcal/kg. to 2.2 Mcal/kg. results in improved utilization. Between 2.2 and 3.0 Mcal/kg. the relationship is linear. Further increases result in lowered efficiency of utilization. Again, this general relationship is in keeping with farm observations and the results of feeding trials around the world. The relationship between energy concentration and energy utilization for fattening is most dramatic. Again, this supports the practice of feeding high concentrates to fattening steers.

This system of stating the nutrient allowances for livestock is the first to bring the science of feeding in line with the "art" of feeding. If you have ever observed the old test cow feeder in box stalls, this is what he has done. He keeps adding a little of this and taking away a little of that until he has reached a perfect balance.

One thing the old system did was to assume that since cows were offered forage free-choice, they were going to all eat at the same rate. A good example of this is the high producing cow that is being fed large amounts of grain and is expected to eat the same amount of forage as the cows getting medium levels of grain, but she won't do it. Cows fed a balanced ration will eat according to body size and level of milk production.

Some data from an experiment conducted at the Northwest Branch Station, Calhoun, Georgia, demonstrated how cows will substitute grain for forage if given the opportunity. There were two groups of cows that we will discuss:

Group 1: In 1966-67 they were offered concentrates free-choice in one trough and silage free-choice in another. That year they ate 40 lbs. concentrates and only 20 lbs. silage. Average production was 16,925 lbs. milk with a 3.4 test.

In 1967-68 they were limited to 30 lbs. concentrates and silage consumption went up from 20 lbs. to 56 lbs. Average production was 16,018 lbs. milk with a 3.6 test.

Group 2: In 1966-67 they were offered silage free-choice and 25 lbs. concentrates. They consumed 60 lbs. silage. Average production was 15,194 lbs. milk with a 3.5 test.

In 1967-68 they were limited to 20 lbs. concentrates and silage consumption went up to 79 lbs. Average milk production was 15,260 with a 3.6 test.

I am not trying to build a case here for low grain feeding. Here we have seen levels of grain feeding all the way from 40 lbs. down to 20 lbs. with all producing about the same results. I think this does raise a question. What is the right amount? I think this question needs to be expanded into what is the right kind for a given situation.

Before we do this, I would like to return briefly to the principles of nutrition for milk production. To do this, look at what milk production is, and how it occurs.

What is Milk Production?

On the farm, milk production is measured in terms of the liquid that is sold as milk. In nutrition, milk is a considerably more complex product as it occurs.

The cow does not manufacture a single substance called milk. She manufactures or makes milk fat, milk protein, and milk sugar. These three ingredients are suspended in water along with minerals and vitamins from the blood stream and the finished product is removed from the udder as milk. An important item in this is that each of these ingredients are produced largely independent of the other. This is what makes feeding complicated.

Let us look briefly at each of these items.

Milk fat is a combination of fatty acids. The primary precursor of milk fat is acetic acid. At this point we could get into an in-depth discussion of just how many carbon links, etc., there are. However, the important thing to remember is that milk fat is made from acetic acid and acetic acid is made from the fermentation of fiber in the rumen. The dependence of milk fat formation explains part of the concern for crude fiber in the ration. This is an example of using certain things in a ration to do a specific thing.

Milk Lactose or Milk Sugar

Milk lactose is the largest single component of milk. It is made indirectly from propionic acid derived from the fermentation of carbohydrates in the rumen. The supply of propionic acid is the greatest limiting factor to total milk yield. This comes from the high energy or concentrate portion of the ration.

Milk protein is simply made from the nitrogen or amino acid supply in the blood stream. Within broad limits, the same is true for minerals and vitamins.

For the remainder of my discussion I would like to go into how we are formulating what we call optimum rations and some of the background for it.

Formulation of products and materials has been practiced ever since man discovered that the value of a single item could be greatly changed by the addition of another. These values are further changed by the addition of more items.

A few years ago McCullough had a very catchy illustration on the cover of his paper that he presented at a short course program. He titled it, "The New Math of Feeding Dairy Cattle." He illustrated his title thusly:

$$1 + 1 = 1$$
$$1 + 1 = 2$$
$$1 + 1 = 3$$

The point this illustration makes is that if we combine the right kind of ingredients we make their value far greater than the sum of these ingredients as individuals. For example, if we combine soybean meal with cottonseed meal we have not increased their value. So, in this case, one plus one would equal one. However, if we combine corn and soybean meal, we have greatly increased the value of both. The purpose then, for calculating optimum rations for individual silages is to find that combination of ingredients that will bring out the full potential of that silage.

Dairy scientists have been testing feed ingredients and combinations of ingredients ever since there has been a science in dairying. Their efforts have been to find the proper characteristics and composition of a dairy ration that will allow cows to produce at their maximum level and fit into today's modern dairy farm. We think the ration now being referred to as optimum rations fulfills these requirements. All of the basic dairy cattle nutrition known has been used to develop this system of feeding. The definition of an optimum ration is defined in McCullough's book, *Optimum Feeding of Dairy Animals* as: "An optimum ration for dairy cows is one designed to provide adequate quantities of ration nutrients balanced to provide the necessary precursors for rumen fermentation which will, in turn, provide to the udder, as needed, precursors for the production of the inherited volume of milk with its normal content of milk constituents."

These rations are designed to meet four basic requirements:

1. The ration itself should not constitute a major factor in total feed intake - **the primary factor in feed intake should be the cow herself.**
2. The ration should be of such composition that the cow would receive a balanced ration in terms of the major nutrients. This should be true regardless of the level of intake.
3. The ration, as consumed, should provide a suitable media for rumen fermentation to assure the production of milk of normal fat and solids content.
4. The ration should be capable of complete mechanical handling.

With these basic principles in mind we can begin to draw up some specifications for our formula. Since intake was our first requirement, we will look at that one first. There are about three things from a ration standpoint that affect intake. The first and major one would be digestibility.

The almost simultaneous finding by the Ohio and Georgia Experiment Stations was that 65% to 68% digestibility was the breaking point at which the ration ceased to limit intake and was the basic finding needed for the development of free-choice feeding formulas. Another factor affecting intake is physical form; how bulky or how heavy is the ration? Still another way to look at it is: what ratio of the forage to concentrate would give the greatest total dry matter intake?

Figure 1 will illustrate this point.

This, then, gives us a second thing to consider in setting up a formula. This lets us know then, that if your client's forage is of high quality, we can use as high as 60% forage in the total ration and still get maximum intake. One other question that must be asked about intake is, are all the ingredients offered palatable? If some of the ingredients are known to be unpalatable, then their use must be restricted. This step in the formulating process is to evaluate each ingredient offered for things other than their nutritional value.

One of the other major requirements of these rations was that they must produce milk of normal fat and solids content. The fiber content of the ration directly affects these constituents. Again, the research results of many investigations around the country show that the fiber level of the total ration must be 16% to 20% on a dry matter basis.

With these general principles in mind we are now ready to be more specific about the formula for an optimum ration.

Optimum rations for dairy cows are now approaching the end of their first decade of use. When the idea was introduced by the Georgia Experiment Station, the rations were described in terms of crude protein, crude fiber, and TDN. Since then, the ration description has been further researched and additional factors have been added. In December of 1973, the requirements of optimum read as follows:

Item	Minimum	Maximum
Crude Protein (%)	13	14
Crude Fiber (%)	16	20
NE Milk (Mcal/lb.)	.75	–
Calcium (%) (exactly)	0.7	–
Phosphorus (%) (exactly)	0.5	–
Magnesium (%)	0.2	–
Potassium (%)	0.8	–
Percent grain in ration	40	60

To calculate an optimum ration, certain information is necessary. The first thing that is necessary is a silage analysis. This means you must have your client's silage tested through a forage testing program. Then, we must have a list of ingredients and their prices.

The use of current broker prices should be the true least-cost ration, but if all the ingredients are not available in your area, then it is of no value to you. This is why we in Georgia prefer to know what is available and at what price. The total cost will be a minimum based on the prices used.

Upper limits have been placed on some of the ingredients to insure palatability and a ration with correct physical form. This feeding system is designed to make maximum use of a producer's silage. As was pointed out earlier, 1,200 lbs. of silage dry matter is the maximum that may be employed and still maintain maximum intake. If the quality of the silage is not good enough to maintain our optimum standards, the computer is programmed not to use 1,200 lb. of silage.

To further illustrate the principles of formulating optimum rations, we have selected four (4) silage samples. Each of these silages represent different problems in formulating optimum rations. Silage number one is a wheat silage. You will note that the analysis is 22% D.M., 12% C.P., and 40 T. of E.N.E. The problem to be solved here is low energy and high fiber. For this silage sample you will note that the computer selected high energy and low fiber ingredients.

Silage number two is an excellent corn silage. Just because it is an excellent corn silage doesn't mean that you can feed just any concentrate mixture with it and get good results. This silage is 35% D.M., 8.7% C.P., 21% C.F., and 63 T of E.N.E. The energy in this silage is already above the minimum requirements that we have established. You will remember that Figure 2 showed that 40% concentrates were necessary to get the density of the ration up for maximum intake. So, the problem here is what kind of a concentrate mixture can we come up with that we can add to this silage at the rate of 40% of the total ration and still maintain 16 to 20% fiber that is necessary for normal rumen fermentation. This makes a rather unusual looking ration. However, it is interesting to note that the total optimum ration analysis is almost identical in all four of these situations.

Silage number three is an early cut corn silage as indicated by the low dry matter content. There are no unusual problems involved with this silage. As you can see, it makes a rather conventional concentrate mixture.

Silage number 4 is an earless corn silage, typical of those found in certain areas of Georgia within the last several years. However, as you can see from the analysis it was cut early enough to maintain adequate moisture and nutrient levels. The problem here, as with the wheat silage, is low energy. This makes a very simple mixture; only corn and soybean meal, plus minerals, were needed to balance this silage.

To feed these optimum rations it is obvious that we must know how many pounds of silage we are putting in the feed bunk each time it is filled. This is necessary, of course, to get the amount of concentrate added to the silage so that a proper silage concentrate ratio is fed.

This feeding program has been developed to take into consideration as many known feeding principles as possible. This feeding program has attempted to create a feeding environment that will allow cows to satisfy their nutritional needs themselves. This does not preclude the need for good herdsmanship. You should constantly and routinely pressure your clients to observe the cow's eating habits and make minor adjustments based on what experience has taught you to be necessary. The calculations were based on chemical analysis of the silage. Often there are certain characteristics of the silage that this analysis will not reveal. Such things as contamination from weeds or poor fermentation will reduce palatability and lower intake. Adjustments for this must be made in order to insure suffient nutrient intake for good production.

In addition to on-the-farm use of the concept either in part or as a total program with excellent results, many experiment stations have conducted related research. The concept appears now to be a permanent part of the dairy feeding programs available for use by dairy farmers.

Some of the more frequently asked questions and research related to answering them are the subject of this discussion.

1. *Question:* What happens when high and low producing cows are fed the same rations?

Answer: California workers looked at this by feeding three groups of cows a ration of 40%

Table 1

Performance of Cows Fed a Free-Choice Mixed Ration. (California Data) (Holsteins)

Item	Production Group		
	High	Medium	Low
Milk (lb./308 days)	24,241	15,310	10,054
Fat (%)	2.9	3.0	3.2
Fat (lb./305 days)	706	455	320
D.M. intake (% body wt.)	3.13	2.45	2.24
Body weight (lb.)	1434	1446	1391
Change in body wt. (lb.)	+106	+74	+130
Energy efficiency (%)			
Total	42.1	33.9	26.1

Table 2

Milk Production, Body Weight Change and Feed Intake of Cows Fed as Individuals or in Group (Purdue University Data) (Guernseys)

Item	Individual feeding	Group feeding
Milk production (lb./day)	35.3	35.1
Milk Fat (%)	5.16	5.26
4% Fat corrected milk (lb./day)	41.3	41.7
Feed intake (% body weight)	3.09	3.32
Average body weight (lb.)	1206	1201
Gain in body weight (lb./day)	1.05	.98

roughage to 60% grain on a free choice basis. The cows were grouped according to expected levels of production.

The data in Table 1 shows the results.

The high producing cows consumed more feed and used it more efficiently than the low producers. Over the entire lactation, there was little evidence of excessive weight gain in any group. Thus, as pointed out in the original Georgia research, high producing cows eat more and are more efficient users of feed while the opposite is true of low producers. This is the basic reason why one ration will work across levels of milk production.

2. *Question:* What about individual vs. group feeding of the same ration?

Answer: Purdue University research shown in Table 2 indicates that the group-fed cows will consume about 7% more feed than the individually-fed cows on the same ration. The requirements of group-fed cows are slightly higher, resulting in nearly identical levels of milk production.

3. *Question:* Would a feeding program which provides high levels of grain in early lactation and low levels at the end of lactation produce more milk than feeding one ration throughout?

Answer: Research workers in North Carolina studied this problem in terms of total lactations. Using 87 first lactations, 53 second lactations and 27 third lactations, they compared the feeding of equal amounts of TDN daily with feeding 61% of the TDN during the first 180 days of lactation and 39% during the remainder of the year. Following three years of research the investigators concluded that "moderate underfeeding during early lactation is not detrimental if mid-lactation, late-lactation and dry period feeding is adequate for persistent production and the regaining of body tissues lost in early production."

What appeared as a radical departure from practice a decade ago has now become a proven practice. As such, it is not the *only* way to feed dairy cows. In general, it has resulted in an increased milk per cow in most herds. This increase generally reflects the fact that cows being fed grain in the milking parlor and roughage outside are being either underfed or fed an unbalanced ration. The tendency for high and low producing cows to consume the same ration without one becoming dangerously thin and the other excessively fat has been substantiated and explained. The ability of the dairy cow to store energy at the end of one lactation for use at the beginning of the next has been confirmed. In short, the concept of optimum rations has met the test of research and the approval of the cow, only the consent of the dairyman remains.

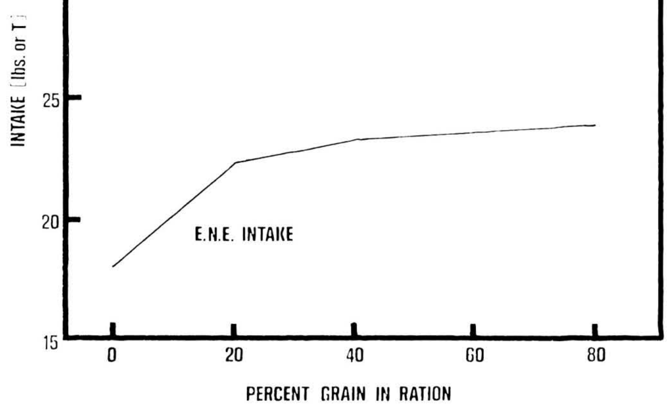

Figure 1. The relationship between percent grain in the ration and the intake of dry matter and estimated net energy.

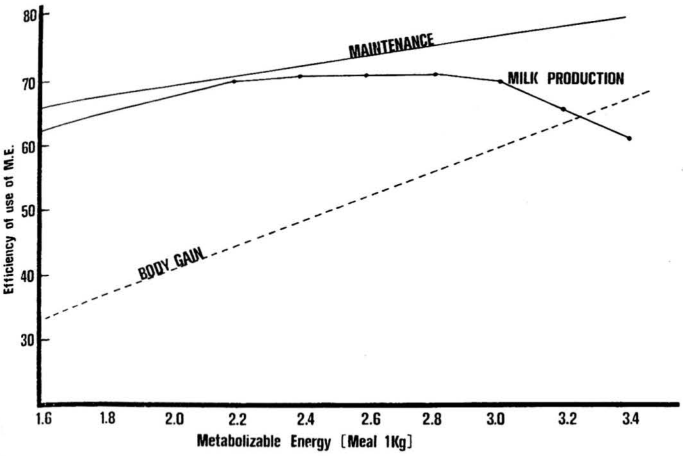

Figure 2. The influence of energy concentration in the ration and the purpose for which the ration is used on the efficiency of energy utilization.

Silage No. 1

Analysis From Forage Testing (Dry Matter Basis)

(Wheat)	Dry Matter	22%
	Crude Protein	12%
	Crude Fiber	35%
	ENE	40T/100 lb.

Calculated Optimum Ration		Grain Ration	
Citrus Pulp	184 lbs.	Citrus Pulp	375 lbs.
Ground Shelled Corn	602 lbs.	Ground Shelled Corn	1221 lbs.
Corn Distillers Grain	69 lbs.	Corn Distillers Grain	140 lbs.
Soybean Meal (50%)	102 lbs.	Soybean Meal (50%)	209 lbs.
Dicalcium Phosphate	27 lbs.	Dicalcium Phosphate	55 lbs.
Silage Dry Matter	1016 lbs.		

Analysis of Total Ration	Analysis of Grain Ration
C.P. 13%	C.P. 14%
C.F. 20%	C.F. 5%
ENE 58 T/100	ENE 76 T/100

Optimum ration obtained by adding 21 lbs. of grain mixture per hundred lbs. of silage.

Silage No. 2

Analysis From Forage Testing (Dry Matter Basis)

(Corn)	Dry Matter	35%
	Crude Protein	8.7%
	Crude Fiber	21%
	ENE	63T/100 lb.

Calculated Optimum Ration		Grain Ration	
Brewers Grain	300 lbs.	Brewers Grain	750 lbs.
Citrus Pulp	117 lbs.	Citrus Pulp	292 lbs.
Corn Distillers Grain	175 lbs.	Corn Distillers Grain	440 lbs.
Hominy Feed	32 lbs.	Hominy Feed	83 lbs.
Soybean Mill Feed	150 lbs.	Soybean Mill Feed	373 lbs.
Dicalcium Phosphate	26 lbs.	Dicalcium Phosphate	60 lbs.
Silage Dry Matter	1200 lbs.		

Analysis of Optimum Ration	Analysis of Grain Ration
C.P. 13%	C.P. 20%
C.F. 19%	C.F. 16%
ENE 65 T/100	ENE 70 T/100

Optimum ration obtained by adding 23 lbs. of grain ration per hundred lbs. of silage.

Silage No. 3

Analysis From Forage Testing (Dry Matter Basis)

(Corn)	Dry Matter	24%
	Crude Protein	11.9%
	Crude Fiber	28.9%
	ENE	60T/100 lb.

Calculated Optimum Ration		Grain Mixture	
Citrus Pulp	150 lbs.	Citrus Pulp	376 lbs.
Ground Shelled Corn	311 lbs.	Ground Shelled Corn	777 lbs.
Corn Distillers Grain	277 lbs.	Corn Distillers Grain	692 lbs.
Hominy Feed	34 lbs.	Hominy Feed	85 lbs.
Dicalcium Phosphate	28 lbs.	Dicalcium Phosphate	70 lbs.
Silage Dry Matter	1200 lbs.		

Analysis of Optimum Ration	Analysis of Grain Ration
C.P. 13%	C.P. 15%
C.F. 20%	C.F. 7%
ENE 62 T/100	ENE 75 T/100

Optimum ration obtained by adding 16 lbs. of grain ration per hundred lbs. of silage.

Silage No. 4

Analysis From Forage Testing (Dry Matter Basis)

(Corn)	Dry Matter	27%
	Crude Protein	11%
	Crude Fiber	33.6%
	ENE	44 T/100 lb.

Calculated Optimum Ration		Grain Mixture	
Ground Shelled Corn	682 lbs.	Ground Shelled Corn	1590 lbs.
Soybean Meal (50%)	142 lbs.	Soybean Meal (50%)	335 lbs.
Dicalcium Phosphate	25 lbs.	Dicalcium Phosphate	55 lbs.
Limestone	9 lbs.	Limestone	20 lbs.
Silage Dry Matter	1141 lbs.		

Analysis of Optimum Ration	Analysis of Grain Ration
C.P. 13%	C.P. 16%
C.F. 20%	C.F. 2%
ENE 58 T/100	ENE 76 T/100

Optimum ration obtained by adding 20 lbs. of grain ration per hundred lbs. of silage.