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The Effects of Forage Quality on Milk Production

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Introduction

Forages are a major source of nutrients needed for milk production. In addition to protein and energy, forages provide the fiber needed in rations for cud chewing, rumination and rumen health. In the formulation of diets for dairy cattle, the quality and the amount of forage needed to meet nutrient and fiber requirements must be considered first. Grains, proteins, co-product feeds and other supplements are added to complement the nutrient contributions from forage. The importance of forages as the foundation of dairy diets was recently illustrated by Lundquist (9) in a feeding pyramid for dairy cattle (Figure 1).

Forages affect dairy rations in two ways: 1) by their contribution of nutrients to the diet and 2) by their impact on ration costs. The quality of a forage affects its ability to contribute nutrients to the diet. High quality forages are able to supply the most nutrients and will have a larger inclusion rate in diets than lower quality forages. For most dairy producers, the least-cost source of nutrients is high quality forages whether they raise their own or purchase them. Additional feeds may be needed in diets utilizing low quality forages raising the cost of the ration.

Legumes, grasses and corn silage are the most commonly fed forages. Alfalfa, the most commonly fed legume, is an excellent source of protein, energy and fiber for dairy cows when the quality is high. Grasses tend to be lower in protein and energy than legumes, but can be a valuable source of nutrients. Both of these forages complement the low protein, high energy qualities of corn silage when combined in diets. The focus of this paper is to examine the impact of legume/grass forages on milk production and evaluate the cost of feeding as affected by forage quality.

Forage Quality – Legume and Grasses

The quality of legumes and grasses is generally assessed by the type and quantity of fibrous material in the plant. Neutral detergent fiber (NDF) is the cell wall material of the plant and is comprised of the hemicellulose, cellulose, and lignin. Increasing levels of NDF in plants and/or diets have been found to limit dry matter intake (DMI). Acid detergent fiber (ADF) is comprised of cellulose and lignin and is closely associated with digestibility. An increase in the indigestible lignin complex in the ADF fraction reduces digestibility of the plant. Therefore, ADF and digestibility are negatively correlated. Protein content of a legume or grass is important, but it does not affect the two more important quality characteristics – intake and digestibility. Quality of legumes and grasses is best estimated by their potential DMI and dry matter digestibility (DDM) which are determined by the NDF and ADF fractions, respectively. Both NDF and ADF increase as the plant matures causing a decline in the quality of the forage.

Relative feed value. Relative feed value (RFV) is an index that combines the important nutritional factors of digestibility and intake into one number which serves as an easy and effective method to evaluate the quality of legumes and grasses (8). The NDF and ADF analyses are used to calculate the potential DMI (eq. 1) and DDM (eq. 2) which, in turn, are used in the RFV equation (eq. 3). The RFV has no units. It is only used as an index to evaluate hay, haylage, legume, grass, or legume-grass mixtures. The RFV compares the feed value of these items to that of full bloom alfalfa which has a RFV of 100. Hays ranked by RFV are assigned to a quality standard grade ranging from prime through decreasing quality of grade 1, 2, 3, 4, and 5 (Table 1). Caution is needed when comparing hays across grades as nearly similar RFVs may be placed in different grades (example: 124 = grade 2, 125 = grade 1) while hays within a grade may have a larger RFV difference (example: RFV 125 to 151 = grade 1). Hays or haylages having a RFV within 10 units of each other should be considered equal in RFV.

(eq. 1) DMI (% of body weight) = 120 / NDF % of forage DM

(eq. 2) DDM (%) = 88.9 − .779 × ADF % of forage DM

(eq. 3) RFV = (DDM × DMI) / 1.29

Effect of Alfalfa/Grass Quality on Milk Production

Forage fed at a fixed amount of the dietary DM. Because stage of maturity (or RFV) is an indicator of fiber content of a forage, there may be value in using it for predicting the production of lactating dairy cows. Several studies evaluating the effects of alfalfa/grass maturity on milk production have fed a fixed forage to concentrate ratio to determine differences in hay qualities. Rations with identical amounts of hay, yet differing in maturity, do not feed the same because mature hays are less digestible. With the less digestible forages, fewer nutrients are provided to the animal for milk production or growth. The following studies have evaluated the effects of forage quality on lactation performance when forage was fed at a fixed amount of the diet.

Kawas et al. (7) fed four hays ad libitum which differed in maturity (pre, early, mid or full bloom) with 20, 37, 54 or 71% concentrate (DM basis) to lactating dairy cattle. Stage of maturity and concentrate levels affected DMI. Cows fed pre-bloom alfalfa hay ate more DM across all four concentrate levels than cows fed the three lower quality hays. Within each stage of alfalfa maturity, DMI and DDM increased as concentrate level in the diet increased. Actual and 4% fat corrected milk (FCM) yields were highest for cows fed the pre-bloom alfalfa. Early bloom alfalfa hay diets needed to contain 54% or more concentrate to support a milk production equivalent to pre-bloom alfalfa hay diets with less than 54% concentrate. Milk productions were lowest on the mid and full bloom alfalfa hay diets and even addition of concentrate up to 71% of the DM did not increase milk production equal to pre-bloom alfalfa.

Turnbull et al. (12) fed four hays differing in quality to evaluate RFV and its associated affect on milk production. Hays of 174, 141, 118 and 99 RFV were fed at 45% of the dietary DM. Average daily milk yield decreased (66.6, 64.2, 63.9, and 60.8 lb) with declining hay quality ($P < .001$). Milk fat percentage was lowest for the 174 RFV hay but 4% FCM was not different between treatments. Cows on the highest quality hay were more persistent throughout lactation. Differences in milk production and persistency reflect the greater available energy content of higher quality hays as the DMI of cows fed diets containing 174, 141 or 118 RFV hays was equal (3.4% of body weight). The lower quality 99 RFV hay did result in a lower ($P < .05$) DMI (3.1% of body weight).

Alhadhrami and Huber (1) fed five hays differing in ADF (26-AZ, 26-CA, 28, 32 and 38%) at levels of 35 or 50% of the dietary DM. Relative feed values of the hays were 177, 171, 165, 147 and 112. Cows fed hay of 165 RFV or above averaged 6.6 lb/day more milk than those fed the 147 or 112 RFV hay. Level of concentrate did not affect milk yield. However, cows did respond to the amount of concentrate in the diet as the efficiency of feed utilization (lb milk/lb DMI) was higher for 65% than for 50% concentrate and tended to be higher for cows fed hay at 165 RFV or above.

Using a pre-bloom and 10%-bloom alfalfa (RFV 154 and 120, respectively), DePeters and Smith (4) looked at hay quality affects on early lactation performance of cows fed 50% or 30% concentrate. Multiparous cows receiving diets containing 50% concentrate produced more milk than those receiving 30% concentrate for both hay qualities. A similar trend was seen in the primiparous cows although not statistically significant. Multiparous cows fed the pre-bloom hay at 50% of the diet showed higher peaks compared to the other three treatment groups. The high quality alfalfa hay increased milk yields a total of 595 lb (primiparous cows) and 882 lb (multiparous) during the first 14 weeks of lactation. Using the high quality alfalfa with 30% concentrate resulted in milk production comparable to diets containing lower quality alfalfa with 50% concentrate. Fat content of milk was slightly higher in cows fed the lower quality hay (3.50 vs. 3.26%). Multiparous cows fed low quality alfalfa lost 48.5 lb of weight during early lactation compared to 1.5 lb loss for cows fed 154 RFV hay. A similar trend was seen in the primiparous cows as those fed 120 RFV hay lost 50 lb more weight during early lactation than cows fed the 154 RFV hay.

The effect of alfalfa maturity on milk production increases as producing ability of cows increases. Alfalfa silage (early, mid, or late cut) was fed at 55% of the diet DM (11). Cows were assigned to three treatments according to milk production; averages for the three groups were 74.5 lb (high), 59.7 lb (medium), and 45.2 lb (low). Alfalfa maturity had the greatest effect on milk production in the high production group decreasing it 3.1 and 9.0 lb/day for the mid and late cuts, respectively, relative to the early cut. Maturity had no affect on milk production when cows produced less than 55 lb/day. For high producing cows (over 60 lb/day) it was concluded that for each day harvest is delayed past mid-bud stage, a reduction of .22 to .33 lb milk/cow/day can be expected when alfalfa silage is fed at 55% of the diet DM.

Feeding forages for optimum fiber levels in diets. When feeding different forage qualities, it is necessary to adjust the amount of forage in the diet to obtain the optimal amount of fiber needed for milk production, maximum nutrient intakes and good rumination. Low quality forages will meet the optimum fiber requirements at a lower percentage of the dietary DM than high quality forages. The following studies have evaluated forage quality in relation to fiber concentration of the diet.

The level of NDF or ADF required in the diet to support the maximum yield of 4% FCM was found to be similar in studies by Kawas et al. (6) whether pre, early, mid or full bloom hay was fed.

However, at the same level of NDF in the diet, milk yield was significantly decreased (P< .05) as forage maturity increased. Milk production decreased 13, 23 and 23% from the pre-bloom alfalfa when early, mid or full bloom hays, respectively, were fed. In addition, fiber components were related to body weight change. During the period of 10 to 26 weeks post-partum, 29% NDF and 20% ADF were the maximum levels possible in diets to sustain milk yields above 77 lb/day and maintain a positive body tissue balance.

Beauchemin (2) varied forage to concentrate ratio to evaluate the effects of dietary NDF concentration and hay quality on the performance of dairy cows. An early (154 RFV) and mid (115 RFV) bloom hay were fed at 31, 34, or 37% NDF of dietary DM. Because of high NDF concentration in the mid-bloom hay, diets using the hay averaged 61% concentrate while those with the early bloom hay averaged 44% concentrate. Therefore, cows fed diets of mid-bloom hay consumed more total energy than those fed early hay. Milk production decreased as dietary NDF increased from 31 to 37% (P < .10). At similar dietary NDF concentrations, hay maturity had no affect on milk production or milk composition. Increasing the concentrate portion of the diet was able to compensate for the lower digestible energy content of hays with higher NDF.

Alfalfa hays were harvested by Kaiser and Combs (5) at the early vegetative (RFV 177), late bud (RFV 105) and full bloom (RFV 103) stage of maturity and fed in diets formulated to contain equal concentrations of NDF (29.4%) and NDF from forage (22.0%). The forage to concentrate ratio of the early vegetative diet was 68:32 compared to 53:47 for the late bud diet and 45:55 for the full bloom diet. No differences in milk production, milk composition or DMI were observed between treatments when fed to cows in early lactation. Results from this study indicate high quality forages can be incorporated into diets at a greater percentage of the DM than low quality forages without any loss in animal performance.

Cleale and Bull (3) harvested mixed grass and legume silages at early and late maturities to determine the effect of forage maturity in isocaloric and isonitrogenous diets on performance of lactating cows. Because of greater digestibility and protein content, early cut silage was incorporated into the diet at 40% of the DM compared to 22% of the DM for late cut silage. Dry matter intake as a percent of body weight did not differ for the diets. Milk yield, 4% FCM and milk fat percent did not differ. Concentrate needed in the diet increased by about one percentage unit for each day harvest was delayed past early cutting as defined in this study. This study again shows the addition of concentrate to the diet can compensate for the nutrient and digestibility declines of forages with increasing maturity.

When orchardgrass and alfalfa silage contain similar ADF concentrations, no differences in milk production were observed when fed in diets containing 40 to 60% concentrate (13). Differences in silages were apparent when fed at 80% of the dietary DM as cows fed orchardgrass produced less (P < .05) milk and consumed less DM than those fed 80% alfalfa silage. Dry matter intakes increased (P < .01) as concentrate level increased, and were higher (P < .01) for alfalfa diets than orchardgrass diets.

Combined Studies – Legumes/Grasses

Dry matter intake, milk and 4% FCM production data from the studies cited above are shown in Table 2. These studies evaluate the overall effect of forage quality on milk production. Relative feed values were calculated and a quality grade assigned to all forages. The percent of Net Energy-Lactation (Mcals) supplied by the alfalfa/grass in the ration was calculated and plotted against milk production (Figure 2). Feeding prime quality alfalfa/grass forage resulted in the most milk yield when forage was included at 35 to 65% of the total ration Mcals. With lower quality forages (grades 1 and 2), more grain supplementation was needed and, hence, less Mcals from forage were fed to obtain the highest milk productions. The window for maximizing milk production from feeding prime quality forage was narrower (35 to 65% of diet Mcals) than with lower grades of forage (35 to 75% for grade 1 and 25 to 60% for grade 2).

Feed Costs and Legume/Grass Quality

Besides directly affecting milk production, forage quality also affects the economy of milk production. As the quality of forage decreases, more protein and energy supplements need to be purchased for the ration. Ration costs are dependent on the price of forages and other ingredients available for feeding. A common method of pricing legume/grass forages in Minnesota is by the equation: $/ton of DM = RFV – 25. This equation is based on 9 years of data from quality tested hay auctions.

The four rations in Table 3 illustrate cost changes when forage is either set at a fixed amount in the ration, or variable but balanced to a specified forage-NDF concentration. Alfalfa haylage was held at 40% of the DMI in rations 1 and 2. Rations 3 and 4 were balanced for 22% NDF from forage. In all rations, corn silage was fixed at 10% of the DMI. All rations were balanced for 85 lb of milk and 48 lb of DMI. Haylage (50% DM) price was determined from the RFV equation. Corn silage (35% DM) price was set at $25/ton as fed. Other ingredients were priced at their current market values.

When 40% of the DMI is from haylage, the ration containing 120 RFV haylage (ration 2) was $.07/cow/day lower than ration 1 with 164 RFV. In this scenario, high quality haylage appears to be over-priced relative to its nutrient value compared to the other feeds available. However, if haylage, corn silage and corn are available on the farm, off-farm feed purchases totaled $1.32/cow/day for ration 1 with 164 RFV haylage compared to $1.97/cow/day for ration 2.

No differences in cost per cow per day were found in rations 3 and 4 when NDF from forage (haylage + corn silage) was held constant at 22% of the DM. Again, off-farm purchases of feeds were $.56/cow/day greater for 120 RFV haylage ration compared to the 164 RFV haylage ration.

The problem with computer generated paper rations is their lack of biological sensitivity. The impact of lower quality forages in a ration on feed intakes, digestion and milk production are unknown until the diet is actually fed. The truest evaluation of overall forage quality will be in animal performance and feed costs. Whether high quality forage lowers feed cost per cow per day or feed cost per cwt of milk is dependent on the price of other feeds in the ration and the price assigned to the forage.

However, based on the forage quality studies summarized and ration cost estimates, dairy producers raising their own forages will have the most profitable and greatest milk production when they harvest and feed high quality forages.

Eating Behavior and Forage Quality

Eating behavior is affected by forage quality. The more fibrous a forage is, the longer it takes for an animal to consume a given amount. Alhadhrami and Huber (1) found that as hays increased from 26 to 38% ADF, cows tended to eat more meals per day, spent more time eating per day and the time spent eating per meal increased. The amount of hay in the diet also affected eating activities with more time spent eating when hay was included at 50% of the dietary DM compared to 35%. Total DMI per day was not affected by ADF content of the hay or level of concentrate in the diet. In diets containing either mid-bloom or early bloom hay, Beauchemin (2) found the total time spent chewing per day increased and the number of chews per day increased linearly with increasing NDF concentration in the diet. This increase was caused by more time spent eating rather than a change in rumination.

Implications of this feeding behavior may be important in freestall barns where bunk space is inadequate. When forage quality is low, more time will be required to consume feed. In over crowded situations, competition for the feed will restrict the time cows have to eat; thus, milk production will decrease as feed intake declines.

Cows can also sort out fibrous particles. A large increase was found in the ADF and NDF concentration of feed refusals when hays utilized in the diet were greater than 30% ADF compared to higher quality hays of 26 and 28% ADF (1). Because of tendencies to sort out the fibrous particles, feeding low quality, long stem forage separately may result in less than desirable fiber intake. Sorting can result in consumption of rations different from those designed to be fed. Total mixed rations and chopping may alleviate some of the sorting.

Summary

Forage quality is important in lactating dairy rations. High quality forages offer greater DMI and digestibility than low quality forages. Their inclusion rate in diets is higher and the contribution of nutrients to the diet is greater than low quality forages. The impact of forage quality on feed costs is variable, but as quality increases, less complementary protein and energy supplementation needs to be purchased.

Differences in forage quality when diets are maintained at a constant percent of forage are readily apparent. Milk production decreases when forage quality declines if a similar forage to concentrate ration is maintained. This concept is important in field application where producers keep the forage at a constant amount in the diet from year to year, regardless of quality.

When diets are balanced on forage-NDF levels, the effect of forage quality is not usually a production response. Good quality forage can be included in the diet at higher levels when compared to low quality forages. As a result, more total Mcals of energy needed for milk production are able to come from the high quality forage.

In the examples of balanced rations, amount of purchased feeds increased in rations utilizing a lower quality forage. When rations were balanced to include equal amounts of forage, or equal forage-NDF levels, rations containing the 120 RFV hay resulted in higher off-farm feed costs as compared to the 164 RFV haylage. The true animal performance response is not reflected in the computer generated rations.

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Table 1. Quality standard grades of hay as determined by the Relative Feed Value (RFV) equation (8).

Grade	RFV
Prime	> 151
1	125-151
2	103-124
3	87-102
4	75-86
5	< 75

Table 2. Summary of diets with different quality forages or fed at different amounts of the diet.

Reference		Treatment	Inclusion	DMI	Milk	4% FCM
			% of diet	------- lb/day -------		
6		Pre-bloom	Avg. NDF[1]	N/A	N/A	82.0
		Early bloom	Avg. NDF[1]	N/A	N/A	71.6
		Mid-bloom	Avg. NDF[1]	N/A	N/A	63.5
		Full bloom	Avg. NDF[1]	N/A	N/A	63.1
12	(Exp. I)	111	29.7	N/A	56.2	48.8
		120	29.7	N/A	55.3	48.0
		133	29.6	N/A	56.4	48.3
		143	29.6	N/A	56.6	48.2
12	(Exp. II)	174	45	N/A	66.5	56.1
		141	45	N/A	64.1	56.5
		118	45	N/A	63.8	55.1
		99	45	N/A	60.8	53.2
1		26% ADF (AZ)	50	50.5	68.6	58.3
		26% ADF (CA)	50	52.2	66.1	58.2
		28% ADF	50	57.8	67.9	56.7
		32% ADF	50	55.8	60.8	54.5
		38% ADF	50	51.6	60.8	51.7
		26% ADF (AZ)	35	49.2	71.4	60.7
		26% ADF (CA)	35	53.6	64.4	57.6
		28% ADF	35	50.9	66.1	53.2
		32% ADF	35	56.7	64.6	55.9
		38% ADF	35	51.4	66.1	54.2
4		Pre-bloom (Multiparous)	50	43.0	78.1	69.9
		Pre-bloom (Multiparous)	70	40.4	67.2	62.2
		10% bloom (Multiparous)	50	41.1	69.0	62.8
		10% bloom (Multiparous)	70	43.0	67.4	65.4
		Pre-bloom (Primiparous)	50	33.4	56.8	51.6
		Pre-bloom (Primiparous)	70	32.3	51.8	49.5
		10% bloom (Primiparous)	50	30.1	50.7	48.4
		10% bloom (Primiparous)	70	31.0	45.5	46.1
11	(Exp. I)	Early cut (High producers)	55	54.9	66.8	67.6
		Mid cut (High producers)	55	55.8	65.9	67.9
		Late cut (High producers)	55	52.0	57.8	58.2
		Early cut (Mid producers)	55	50.3	51.1	53.8

	Mid cut (Mid producers)	55	50.5	53.1	53.9
	Late cut (Mid producers)	55	48.9	52.2	53.0
	Early cut (Low producers)	55	43.7	37.7	39.7
	Mid cut (Low producers)	55	44.8	40.3	40.8
	Late cut (Low producers)	55	40.8	35.3	37.5
11 (Exp. II)	Early cut (silage)	55	48.5	60.0	59.4
	Mid cut (silage)	55	49.2	59.5	57.9
	Late cut (silage)	55	49.6	61.1	60.7
	Early cut (hay)	55	44.3	58.6	55.0
	Mid cut (hay)	55	41.2	56.2	54.4
	Late cut (hay)	55	42.1	56.2	53.9
10 (Exp. I)	Early cut (hay)	60	39.7	67.7	60.9
	Late cut (hay)	60	40.8	70.8	64.8
	Early cut (silage)	60	44.5	74.1	67.1
	Late cut (silage)	60	41.9	73.6	65.8
10 (Exp. II)	Early cut (hay)	60	49.8	77.2	71.7
	Late cut (hay)	60	48.3	77.2	72.0
	Early cut (silage)	60	47.8	84.0	79.5
	Late cut (silage)	60	49.8	81.6	74.8
2	Early bloom (31% NDF)	37.2	49.2	59.5	49.3
	Mid-bloom (31% NDF)	26.3	49.6	59.1	45.8
	Early bloom (34% NDF)	55.8	48.9	59.1	50.9
	Mid-bloom (34% NDF)	39.3	49.6	56.7	48.5
	Early bloom (37% NDF)	74.4	47.2	55.1	49.3
	Mid-bloom (37% NDF)	52.4	49.8	54.0	48.4
5	Early vegetative	68	55.3	79.6	71.2
	Late bud	53	54.9	83.1	73.5
	Full bloom	45	57.1	82.2	71.4
3	Early cut	39.7	33.6	52.3	46.4
	Late cut	22.1	37.2	57.1	48.9
13	Orchardgrass	80	37.7	46.5	43.6
	Orchardgrass	60	45.2	59.1	52.7
	Orchardgrass	40	48.1	58.6	52.1
	Alfalfa	80	47.0	52.5	51.4
	Alfalfa	60	49.4	60.2	51.7
	Alfalfa	40	51.1	61.1	52.3

[1] Treatments were averaged across dietary NDF levels which supported maximum milk yields.

Table 3. Forage quality and ration costs.[1]

	Haylage - 40% DMI		22% NDF-Forage	
Ration:	1	2	3	4
Item Haylage RFV:	164	120	164	120
Feeds (as fed basis, lb/day)				
Haylage - 50% DM	38.0	38.0	39.5	32.6
Corn silage - 35% DM	14.0	14.0	14.0	14.0
Corn	11.6	6.8	11.5	12.1
Cottonseed	5.1	7.0	4.5	3.0
Corn gluten feed	8.0	8.0	8.0	8.0
38% protein	1.6	3.7	1.6	5.9
Fat	.0	.8	.0	.5
Mineral/vitamin	.5	.4	.4	.3
Total	78.8	78.6	79.4	76.4
Nutrient Composition – Ration (DM basis)				
CP, %	17.5	17.5	17.5	17.5
ADF, %	19.0	23.0	19.0	19.0
NDF, %	33.2	38.7	33.2	33.7
NDF-forage, %	21.7	26.6	22.0	22.0
NE_L, Mcal/cwt	79.4	79.0	78.9	79.0
NFC, %	36.5	29.8	36.7	37.0
Fat, %	5.6	6.9	5.1	5.3
Ration costs[2]				
Farm feeds[3]	2.22	1.50	2.26	1.70
Off-farm[3]	1.32	1.97	1.26	1.82
Total	3.54	3.47	3.52	3.52

[1] Ration balanced for 85 lb milk, 1350 lb cow, and 48 lb DMI.

[2] Feed prices ($/ton): 164 RFV haylage ($68), 120 RFV haylage ($47.50), corn silage ($25), corn ($125), cottonseed ($200), corn gluten feed ($135), 38% protein ($275), and tallow ($400).

[3] Farm feeds include haylage, corn silage and corn. Off-farm feeds are all others.

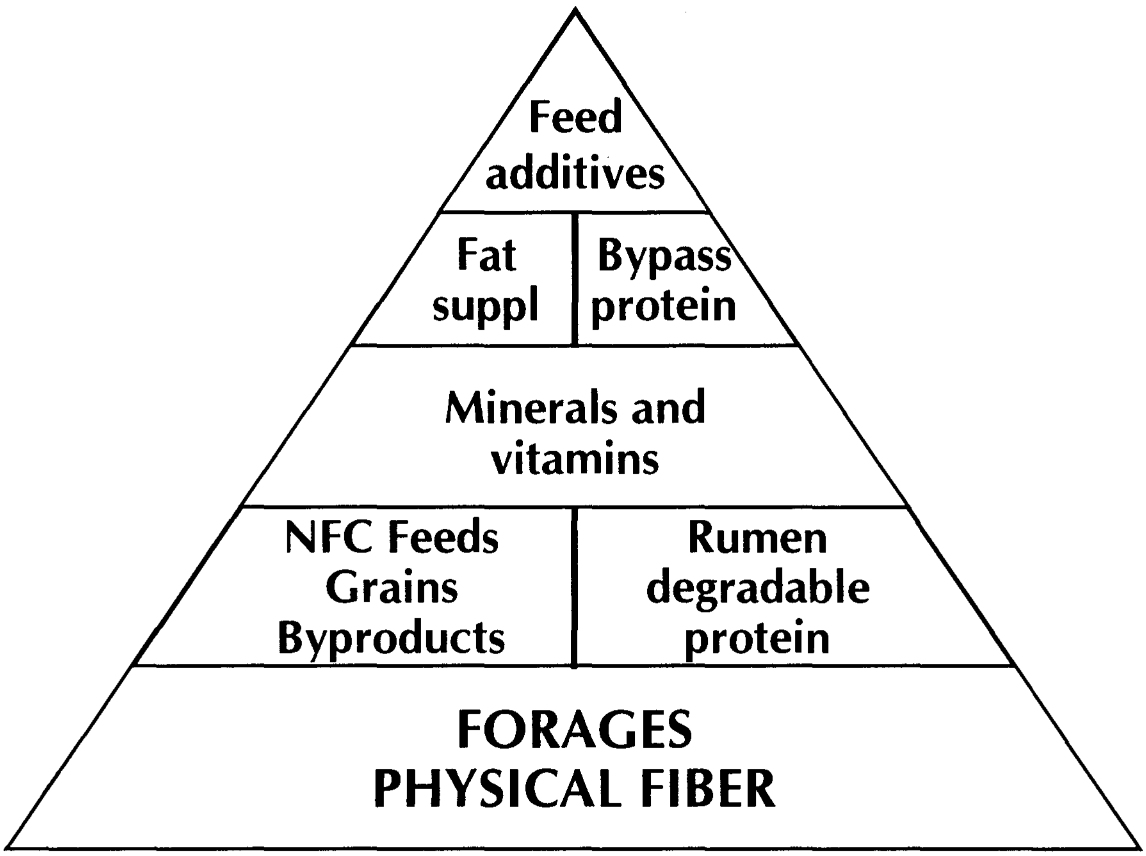

Figure 1. The feeding pyramid (9).

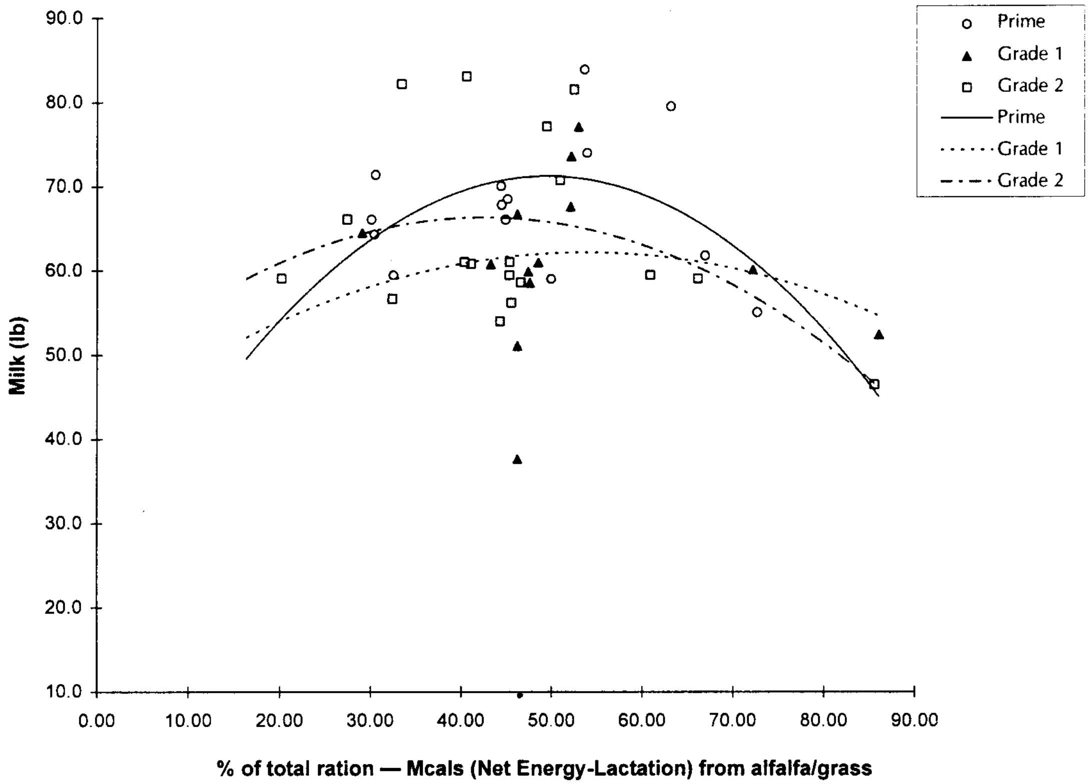

Figure 2. The effect of forage quality on milk production.