Feeding the Grazing Dairy Cow[a]

Tony R. Rickard
Dairy Specialist
University of Missouri Extension

Interest and growth in pasture-based dairy systems continues to grow, as experienced in Missouri and other states. This type of system, however, presents interesting challenges to producers and nutritionists as they attempt to optimize pasture utilization, yet supplement at a level that maximizes financial return.

In a confinement system, the producer has more control over all ingredients in the ration, particularly with the forage component. Whereas, in a pasture system, more unknowns are involved with this component and the consistency of nutrient intake each day. This can lead to more variability in production from one day to another, but in no way implies that high, profitable milk production can not be attained. It is not unusual to see pasture-based systems producing up to 20,000 lbs. of milk in a properly managed herd.

Whether it is a pasture-based or confinement dairy operation, the most critical component a producer must take into account is INTAKE, INTAKE, INTAKE. Add to this, the intake has to be of high quality and sufficient availability to not be a limiting factor. Too often we see instances of producers attempting to “starve” milk out of their cows by cutting costs and all it does is decrease the profitability of their dairy.

Pasture Quality

Much of the variability in quality observed in our paddocks can be attributed to stage of maturity, but it can also be influenced by species, fertilization and environmental conditions in which the forage is growing. Generally, in comparing well-managed pasture to stored forages, they will be higher in total protein and rumen degradable protein, lower in fiber and higher in energy. Similar to stored forages, pastures will also be lower in Non-structural Carbohydrates (NFC), which represents the sugars and starch fractions. NFC levels are inversely related to stage of maturity and has a direct effect on the types of grains included in the supplement mix.

Novice grazers are quite surprised at the quality observed in pasture samples. Muller (2002) summarized six studies looking at typical nutrient analyses of pastures over the grazing season and these are presented in Table 1. Crude protein values in this summary ranged up to 26% and total fiber levels (Neutral Detergent Fiber, NDF) normally less than 40%, but going up to 55% in the summer. Personal observations of analyses in Missouri would show spring grass samples to have in excess of 34% crude protein, but similar NDF values.

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Good grazing management, which keeps pastures in a vegetative stage of growth, will result in high quality pastures even in the summer. Protein and energy levels are normally lower and fiber levels higher during the summer as depicted in this table.

Using averages as presented in Table 1 to demonstrate the type of quality one can expect in a pasture-based system is acceptable, but should not be used as the "true values" for a specific farm. This can only come about by actually sampling paddocks on that farm. As a nutritionist, it would be far easier to formulate a grain mix if every paddock was sampled each time the cows entered. In working with grazers, this is an unrealistic expectation and what is practical has to come into play. As a minimum, producers should sample as many samples as acceptable the first year to begin to build a data base of what can be expected with your management, environmental conditions that year and the type of forages being grazed. Knowing these values will not hold true from year to year, some sampling needs to be done each year to continue to build on this base. It is not possible to accurately predict precise nutrients in a given paddock, but personal observations of our more successful and experienced dairy grazers has clearly demonstrated they can come very close.

Pasture Dry Matter Intake (DMI)

One of the largest issues facing the grazer is estimating pasture intake. Animal-based techniques involve the use of chromium oxide or alkanes to measure rate of passage. This approach is used in research, but is unpractical and impossible for the typical dairy operation. In practice, the expected total DMI as outlined by NRC is determined and then the amount of grain and supplemental forage dry matter is subtracted from this total and an "estimated" pasture DMI is calculated. This calculated value will depend on a consideration of the factors involved in pasture management.

Actual pasture DMI is a product of grazing time (min/d), biting rate (bites/min) and dry matter (DM) bite mass or size (g DM/bite). The latter has the greatest impact on intake and is dependent on pasture-related characteristics such as pasture height and density.

Grazing Time (min/day)
X
Biting Rate (bites/min)
X
Bite Size (g intake/bite)
↓
Pasture Intake

Gibbs et al. (1997) reported that for dairy cows continuously grazing ryegrass, bite size decreased from 0.31 g organic matter/bite at 2.7-3.5 inches of grass to 0.23 g organic matter at 1.9 inches. Neither biting rate (76 bites/min) nor grazing time (604 min/d) were affected by pasture height. McGilloway et al. (1999) observed that bite size decreased from 1.28 g DM/bite at 8.3 inches of sward height to 0.66 g DM/bite at 2.7 inches. In another experiment, they found an interaction between pasture height and density; bite size was reduced with reductions in pasture height more at low pasture density than at high pasture density as expected.

Grazing time and biting rate are influenced by animal characteristics such as genetic merit and milk production. Grazing time and biting rate act as compensatory mechanisms to alleviate reductions in pasture DMI, but there is a limit to this mechanism. Under poor pasture conditions (e.g., very short pasture) all three variables decline (Hodgson and Brookes, 1999).

Effect of Supplementation on Grazing

In a New Zealand scenario, where producers are paid on the basis of milk solids, discounted for volume and grain is high priced, few dairies feed supplemental grains. In the US payment is based on butterfat and protein (in some Orders) and volume. In these cases, considering the relatively low price of concentrate, it is normally advantageous to feed at least minimal levels of grain. Then the question becomes one of what effect does supplemental concentrates have on dry matter intake of pastures.

Table 2 is a summary by Bargo et al. (2003) of several studies looking at the effects of supplementation on grazing time, biting rate and bite size (or mass), all of which determine how much DM the cow consumes. The data consistently shows the addition of concentrate reduces grazing time (minutes), but does not affect biting rate. In the study by Arriaga-Jordan and Holmes (1986) they reported grazing time was reduced by 5 minutes/lb of concentrate in continuous grazing systems and almost 4 minutes/lb of concentrate in rotational grazing, while biting rate was not affected by the amount of supplementation. Gibbs et al. (2002) reported that as concentrate increased from 2.6 lb. to 13.2 lb/day grazing time of cows on ryegrass pastures decreased from 591 to 572 minutes/day, or 19 minutes per day.

If one averages supplementation rates for all of the trials (average of 9 lb/day, range of 4.4-17.6 lb/day) grazing time was reduced by 34 minutes per day but biting time and biting size (mass) was not affected.

The net effect is a significant reduction in pasture DM intake and one has to determine if any observed increase in milk production is a profitable response, taking into account the substitution of higher priced grain for lower priced pasture. Unpublished data from Missouri dairy grazers would indicate a pound of DM pasture costs approximately $0.02/lb, not including land costs.

Substitution Rate

After the proceeding section it becomes quite obvious that when grazing dairy animals are fed supplements, pasture DMI normally declines due to a decrease in grazing time. This is known as substitution rate and is a major factor in the variation in milk response when supplements are given, where milk response to supplementation is expressed as lb milk/lb supplement. Normally there is a negative relationship between substitution rate and milk response. Table 3 lists several research trials that looked at the affects of supplementation and pasture allowance on substitution rate. Substitution rate was quite variable, ranging from 0.14 to 0.65, but was not significant.

One factor affecting substitution rate is pasture allowance, or the amount of pasture DM made available to each cow in the paddock and three studies looking at this are included in Table 3. The data show that as pasture allowance increases, the substitution rate increases, but the milk response/lb concentrate decreases. Where pasture allowance was determined as being low (<55 lb/day) by the authors, the average substitution rate was 0.2 lb/lb concentrate and at high allowance (>55 lb/day) the average substitution rate was 0.62 lb.

The higher substitution rate at high pasture allowance may be due to the higher quality of pastures actually consumed by the cows. Since there are excessive amounts of pasture available, they can be more selective in the forages grazed and they will certainly have a higher digestibility than forages found at lower pasture allowances. From a practical standpoint this results in very inefficient use of pasture and would not be applicable to the typical dairy grazing operation.

Type of Supplement

Forage

The type of supplement given to grazing cows also influences substitution rate and performance. Mayne and Wright (1988) observed a higher substitution rate for forage supplementation than for concentrate supplementation. Including both low and high pasture allowances, substitution ranged from 0.84 to 1.02 lb/lb for grass silage supplementation and from 0.11 to 0.50 lb/lb for concentrate supplementation. Similarly, Stockdale (1999) reviewed 39 sets of data and concluded that supplementation with forages, such as hay or corn silage, resulted in higher substitution rates than that with concentrates. These studies would question the practice of putting out hay to cows in a pasture-based system.

Starch vs. fiber-based concentrates

Several studies are listed in Table 4 comparing starch or fiber-based concentrates for cows on pasture or cows fed fresh-cut forage in confinement. Sources of starch included corn, cassava barley or the combination of barley, wheat and corn. Sources of fiber included oatfeed, beet pulp either alone or combined with soy hulls or citrus pulp.

In the grazing studies, pasture and total DMI increased between 1.5-1.8 lb/day when fibrous type feeds replaced starch-based concentrates for cow grazing ryegrass pastures. Late-lactation cows grazing orchardgrass showed no difference in total or pasture DMI regardless of concentrate source.

In the confinement studies, where fresh-cut forage was brought to the cows, they showed similar DMI’s and similar or lower total DMI regardless of concentrate source.

Overall, fiber-based concentrates slightly increased pasture DMI about 0.3 lb/day, but there was a large variation (-1.54 to 3.1lb/day). The limited number of trials would indicate there is no significant difference with the type of concentrate, but there is large variation in what levels were supplemented. In the authors opinion, the two trials not following the general trends in the others was that of Delahoy et al. (2003) in which cows received either 18 pounds of corn-based grain or 18 lbs of a fibrous ration and there was no difference in pasture or total DMI, nor on milk production, recognizing the cows were much later in lactation. The other is that of Valk et al. (1990) when rations with corn resulted in significantly higher milk production than rations with approximately the same level of beet pulp. The data of Sayers (1999) clearly demonstrates the principal of substitution rate and also acidosis affects of high levels (22 lb/d) of a cereal grain supplementation. This effect would be more pronounced with the barley and wheat starch as the per cent rapidly degraded with these two grains is 66 and 78%, respectively.

Level of Supplementation

Refer again to Table 2 to review studies conducted on dairy cows on pasture and the effects of levels of concentrate supplementation on DMI, substitution rate and milk response. Overall, pasture DMI declined and total DMI increased by increasing the amount of supplementation. Pasture DMI declined as levels of concentrate increased, which is directly related to the substitution of pasture. For the range of supplementation listed (1.8 to 19.1 lb/day), pasture DMI decreased by 13% compared with pasture only DMI studies.

Table 5 is a summary of several studies evaluating the effect of concentrate supplementation on DMI, milk production and composition. Bargo et al. (2003) summarized the studies and found that milk production increased on average about 9.7 lb/day with supplementation or 22% compared with the pasture-only diet treatments. It becomes quite obvious that forage quality is a variable affecting the results presented as one evaluates the level of milk production without supplementation and level of supplement fed, as well as the ingredients composing the supplement, which are all outside of the normal parameters dairy grazers in Missouri follow. For instance, in the study by Reis and Combs (2002), the grain mix is composed of 90.5% corn and was fed at levels of 11 and 22 pounds/day. When milk production was evaluated on a fat-corrected basis, there was not a significance difference between treatments due to the low butter fat test, but there was a significant decline in pasture DMI. Is this profitable?

Rumen Undegradable Protein Supplementation

Eight studies were reviewed looking at various ingredients higher in rumen undegradable protein (RUP) being added to basal rations to evaluate their effect. Rumen Undegradable sources examined included animal protein blend, corn gluten meal, expeller soybean meal, blood meal, feather meal, heat-treated rapeseed meal and fish meal. Only two resulted in a significant increase in milk production. Milk response ranged from 6% (Schroeder and Gagliostro, 2000) using fishmeal to 18% (Schor and Gagliostro, 2001) using blood meal. Based on highly variable responses (six studies showing no response) and the potential cost difference in including these ingredients, in the author’s opinion, more research needs to be conducted before RUP sources are included in pasture-based rations.

One of the factors unaccounted for in these studies is rate of passage observed in pasture-based systems. Even the novice grazer is well aware of stool consistency when grazing high quality pastures, and this rate of passage could overcome the expected responses to the addition of RUP sources.

Fat Supplementation

Whether the dairy operation is pasture-based or confinement, the primary limiting factor to milk production is always energy. Theoretically, the addition of high energy feeds, such as fat, should help alleviate this deficiency. However, as the research is reviewed in pasture systems, the results are inconsistent.

Some of the studies supplemented cows with concentrates with fat sources that partially replaced some of the concentrates or were added to a basal amount of concentrate. Sources of fat included ruminally inert sources such as hydrogenated fish fat, Ca-salts of long-chain fatty acids, high melting point fatty acids or nonruminally inert sources such as full fat rapeseed and soybean oil. The amount of fat supplemented ranged from 0.44 to 2.2 lb/day.

Three studies (Gallardo et al., 2001; King et al., 1990; Schroeder et al., 2002) measured pasture DMI. Two of these showed no difference in pasture DMI when fat was included and Schroeder et al. (2002) reported a linear decrease in pasture DMI as the amount of fat added to the basal diet increased from 0 to 2.2 lb/day. The decrease observed as the upper levels of fat were added was probably attributable to physiological reasons.

The effect of added fat on milk production in a pasture-based system is not consistent. Some studies showed no effect (Garnsworthy, 1990; King et al., 1990; Arenäs et al., 2002) and some studies showing positive effects (Murphy et al., 1995; Gallardo et al., 2001; Schroeder et al., 2002). When Bargo et al. (2003) summarized all of the trials they found no affect on total DMI , but did show a 6% increase in milk production when compared to the no-fat treatments. This would be consistent with the expected response of an ingredient that contains 2.25 times the energy per unit as compared to a unit of carbohydrate or protein.

Summary

Supplementation of dairy cows in a pasture-based system is quite different than that in a confinement operation. More variables are involved, particularly as it relates to intake and the quality of that intake. Unless the grazer has the same strict guidelines as a confinement system as it relates to forage quality, a profitable and sustainable pasture-based system will be impossible. At the University of Missouri SW Research Center, when hay feeding is required, purchased alfalfa must be a minimum of 160 RFV. The sample principles of quality must to be adhered to in our paddocks for a successful outcome.

Definitive research on the level of concentrate to be fed or the ingredients that should be included in that mix is not available. One must look at the research, evaluate the conditions in which it was conducted, and draw inferences that would apply to each farm. Too often we try to make it complex, when we should actually use the K.I.S.S. method.

Research clearly delineates that adding incremental amounts of grain will decrease pasture DMI. Depending on the research reviewed, the substitution rate will range from 0.2 to 0.6 lb of pasture DM per lb of concentrate DM fed. Naturally, the substitution rate increases as the level of concentrate increases. However, this type of substitution can be used to the advantage of the grazer when needed. During 2006 six Missouri dairy grazers have been doing weekly platemeter readings on their paddocks and their grazing wedges can be found at http://agebb.missouri.edu/dairy/grazing/wedge/index.htm During times of surplus forage some grazers reduced levels of concentrate being fed to encourage more pasture consumption to maintain the wedge at optimum quality and then would increase concentrate feeding when pasture availability was inadequate. This is why management is included in any reference to pasture-based dairying when it is referred to as "management intensive grazing." However, if level of grain is used as a means of managing pastures, the composition of the mix will come into play and caution should be exercised at both extremes.

So what should the composition of the concentrate mix be? After reviewing the literature and observing a pasture and total DMI increase of 1.5 to 1.8 lb per day when fibrous type rations were fed, it is logical that highly digestible fibrous components should be a part of the mix. At the same time, recognizing that pasture forages are low in non-structural carbohydrates and is a requirement of rumen microbes, it is also logical that cereal grains would be a critical component. In Missouri, since beet pulp and citrus pulp are not readily available, soy hulls are widely used as the fibrous source and corn as the starch source. A typical Missouri ration would be composed of 60-70% corn and 20-40% soy hulls (minerals, vitamins and other ingredients would need to be added). This combination captures the attributes presented in the studies listed.

At the MU SW Research Center, it is not unusual to see cows milking over 100 lbs of milk per day in the spring when consuming a concentrate mix of 68% corn and 22% soy hulls (plus animal fat, molasses and minerals) with the cows only consuming 8-12 lb per day. When adequate, high quality pasture is available throughout the grazing day, cows will voluntarily reduce concentrate consumption without the aide of the manager. This, plus reviewing results in the studies presented, would suggest the optimum level of concentrate feeding on most pasture-based dairies will be between 8 and 15 lb per day.

As far as the addition of rumen undegradable protein (RUP) and fat, the research is inconclusive. Only two studies showed an improvement in milk production with the addition of RUP. The lack of response is probably more related to rate of passage issues. In the authors opinion, more research is needed before RUP is considered in the ration for grass-based dairies.

On the other hand, added fat has merit. When Bargo et al. (2003) evaluated all of the studies supplementing with fat, they found an overall increase in production of 6%. Since energy is always the primary limiting factor in grazing nutrition, and fat has 2.25 times the energy in a given unit compared to carbohydrate or protein, this author feels fat should be included in grazing rations. A general rule of thumb is to not feed more than 1.0 lb of added fat per cow per day, but personal observations have shown some cows will reduce concentrate consumption at levels of as little as 0.6 lb per day. Add fat slowly to the mix to reduce consumption issues.

Table 1. Average nutrient composition for cool season grass pasture and legumes over a grazing season.[a]

	Predominantly Grass (Cool season)		Grass with Legumes	
Nutrient	Spring	Summer	Spring	Summer
Crude Protein (CP), % DM	21-25	18-22	22-26	20-24
RUP[b], % of CP	20-25	25-30	20-25	25-30
Sol. P[c], % of CP	35-40	25-30	30-35	25-30
ADF[d], % DM	24-28	28-34	21-25	25-30
NDF[e], % DM	40-45	48-55	30-36	35-45
Hemicellulose, % DM	17-21	21-25	12-16	15-19
Cellulose, % DM	16-20	21-26	16-20	18-23
NE, Mcal/lb	0.72-0.78	0.66-0.72	0.74-0.80	0.70-0.74
Non-fiber carbohydrate (NFC), %DM	15-20	12-15	18-24	15-20
Fat, % DM	3-4	3-4	3-4	3-4
Ash, %DM	7-9	7-9	8-9	7-9
Ca, % DM	0.50-0.75	0.50-0.75	1.1-1.3	1.1-1.3
P, % DM	0.30-0.35	0.30-0.35	0.30-0.35	0.30-0.35
Mg, % DM	0.15-0.20	0.15-0.20	0.18-0.24	0.18-0.24
K, % DM	2.0-3.5	2.0-3.5	2.5-3.5	2.5-3.5
S, % DM	0.16-0.22	0.16-0.22	0.18-0.26	0.18-0.26

[a]Muller (2002)
[b]Rumen undegradable protein
[c]Soluble protein
[d]Acid Detergent Fiber
[e]Neutral Detergent Fiber

Table 2. Effect of concentrate supplementation on grazing time (GT), biting rate (BR) and bite mass (BM) of dairy cows.*

	-------Cows[1]------------			---------------Supplement---------		GT	BR	Total	BM
Reference:	DIM	MILK	Pasture[2]	Type[3]	DMI, lb/d	min/d	bites/min	bites/d	gDM/bt
Arriaga-Jordon & Holmes, 1986	72	83.2	RG (rotational)	Barley	2.2	467[a]	64[a]	30,000	0.53 gOM/b
					13.2	424[b]	62[b]	26,100	0.58
			RG (continuous)	Barley	2.2	525[a]	75[b]	39,400	0.47
					13.2	471[b]	75[b]	35,100	0.48
Bargo et al., 2002	101	100.8	OG	Corn	1.8	609[a]	56	34,419[a]	0.55
					18.9	534[b]	54	28,501[b]	0.55
					1.5	626[a]	56	35,235[a]	0.60
					19.1	522[b]	55	28,563[b]	0.59
Delagarde et al., 1997	156	55	RG (0 lb N/acre)	Control	0.0	510	54	27,300	0.47[a] gOM/b
				Soybean meal	4.4	519	56	29,100	0.48[a]
			RG (132 lb N/acre)	Control	0.0	546	54	29,000	0.53[b]
				Soybean meal	4.4	517	54	27,900	0.54[b]
Gibb et al., 2002	52	66.2	RG	Barley	0.0	591	57	32,967	0.32
					2.6	610	60	35,800	0.33
					5.3	605	60	35,067	0.31
					7.9	610	59	32,333	0.33
					10.6	588	61	34,933	0.24
					13.2	572	61	33,400	0.29
Kibon and Holmes, 1987	75	71.3	RG (2 inches)	Control	0	596[a]	78	47,000	0.32[a]
				Cereal	6.6	571[b]	77	44,000	0.36[a]
				Beet pulp	6.6	559[b]	77	43,000[b]	0.35[a]
			RG (2.4 inches)	Control	0	585	76	45,000[a]	0.39[b]
				Cereal	6.6	550	76	42,000[b]	0.39[b]
				Beet pulp	6.6	560	76	43,000[b]	0.40[b]
Rook et al., 1994	48	NA	RG/WC (1.6 inches)	Control	0	765[a]	62	NA	0.28
				CG/beet pulp	8.8	553[b]	45	NA	0.51
			RG/WC (2.4 inches)	Control	0	651	47	NA	0.52
				CG/beet pulp	8.8	660	61	NA	0.33
			RG/WC (3.1 inches)	Control	0	639a	53	NA	0.54
				CG/beet pulp	8.8	606b	52	NA	0.58

*Adapted from Bargo et al., 2003.

[a, b, c, d] Means within reference with different superscript differ ($P < 0.05$).

[1]Pre-experimental DIM and milk (lb/d).

[2]RG=perennial ryegrass; OG=orchardgrass; WC= white clover.

[3]Main source of energy in the supplement.

Table 3. Substitution rate (SR) and milk response (MR) of dairy cows supplemented with concentrates.*

	------------Cows[1]------------			------------------------ Supplement-------------		PA[3]	SR[4]	MR[5]
Reference:	DIM	MILK	Pasture[2]	Type	DMI, lb/d	lb DM/c/d	lb past/lb conc.	lb m/lb conc.
Effect of Pasture Allowance								
Bargo et al., 2002	101	100.8	OG	Corn	17.4	55.0	0.26	1.36
						88.0	0.55	0.96
Robaina et al., 1998	180	45.1	RG/WC	Barley/lupin	9.5	46.4	0.31	0.98
						93.0	0.57	0.54
Stockdale, 1999[6]	106-229	42.5-67.3	RG/WC/P	Barley/wheat	6.6-11.0	66.0	0.43	0.43
						66.0	0.45	0.55
						66.0	0.29	1.18
						88.0	0.43	0.49
						88.0	0.46	0.98
Effect of amount of conc.								
Dillon et al., 2000	31	59.4	RG	Corn/beet pulp	4.4	---	0.46	0.50
					8.8	---	0.18	0.31
				Corn/beet pulp	4.4	---	0.14	0.30
					8.8	---	0.21	0.35
Reis and Combs, 2002	84	91.5	A/RC/RG	Corn	11.0	---	0.24	1.00
					22.0	---	0.41	0.86
Robaina et al., 1998	180	47.1	RG/WC	Barley	4.0	---	0.44	1.56
					7.5	---	0.65	0.94
					14.7	---	0.58	0.82
Effect of type of concentrate								
Sayers, 1998	40	Not avail.	RG	Starch (barley/corn)	22.0	---	0.62	0.68
				Fiber (beet/citrus pulp	22.0	---	0.50	0.86
Schwarz et al., 1995	49	59.4	Grass/legume	Starch (corn)	13.4	---	0.49	0.74
				Fiber (sugar beet pulp)	15.6	---	0.52	0.37
				Starch (corn)	9.9	---	0.27	0.76
				Fiber (sugar beet pulp)	11.4	---	0.31	0.42

*Adapted from Bargo et al., 2003.
[1]Pre experimental DIM and milk production (lb/day).
[2]A = alfalfa; OG = orchardgrass; P = *Paspalum dialatatum*; RC = red clover; RG = perennial ryegrass; WC = white clover.
[3]PA = pasture allowance (lb DM/cow/day).
[4]SR = Substitution rate calculated relative to the unsupplemented treatment (lb pasture/lb concentrate).
[5]MR = milk response (lb milk/lb concentrate).
[6]Data from 7 experiments.

Table 4. Effect of starch (S) or fiber (F)-based concentrate supplementation on DMI, milk production and composition of dairy cows on pasture.*

	Cows[1]				DMI, lb/d			Milk	Fat	Prot.
Reference	DIM	Milk	Pasture[2]	Conc. Type[3]	Amount	Pasture	Total	Lb/d	%	%
Delahoy et al., 2003	182	78.1	OG	S (corn)	18.0	26.6	44.7	60.7	3.53	3.23a
				F (beet pulp/soy hulls)	18.0	26.4	44.4	60.3	3.63	3.19b
Garnsworthy, 1990	NA[4]	NA	RG	S (barley/corn)	8.8	NA	NA	46.9	3.99	3.44
				F (oatfeed)	8.8	NA	NA	50.4	4.27	3.48
Meijs, 1986[5]	60	63.6	RG	S (cassava/corn)	12.1	25.7[a]	37.8[a]	56.7[a]	3.96	3.40
				F (beet pulp/soy hulls)	11.9	27.3[b]	39.2[b]	59.2[b]	4.10	3.37
Sayers, 1999	40	NA	RG	S (barley/wht/corn)	11.0	27.7a	38.7[a]	68.6[a]	3.66[a]	3.37[a]
				F (beet/citrus pulp)	11.0	29.5[b]	40.5[b]	68.0[a]	3.94	3.30[b]
				S (barley/wht/corn)	22.0	9.5[c]	42.9[c]	76.1[b]	2.99[c]	3.55[c]
				F (beet/citrus pulp)	22.0	10.9[d]	46.0[d]	77.4[b]	3.62[a]	3.34[a]
Schwartz et al., 1995	56	62.0	Grass/legumes	Control	0.0 + 0.3 min.[7]	32.8[a]	33.0[a]	44.7[b]	4.16	3.13
(confinement)[6]				S (corn)	13.4 + 0.3 min.[7]	26.2[b]	40.0[b]	54.6[a]	3.69	3.23
				F(mollased sug. bt. pulp)	15.6 + 0.3 min.[7]	24.6[b]	40.7[b]	50.4[ab]	3.90	3.16
Spörndly, 1991	175	56.5	Grass	Control	0.0 + 4.2 hay	32.1[a]	36.3[a]	43.3[a]	4.46[ac]	3.28[a]
(confinement)[6]				S (barley)	7.3 + 4.4 hay	27.9[b]	39.6[b]	45.1[ab]	4.68[b]	3.39[b]
				F (beet pulp)	7.3 + 4.4 hay	27.3[b]	38.9[b]	43.8[a]	4.5[a]	3.44[bc]
				S (barley)	12.8 + 4.4 hay	24.2[c]	41.4[c]	48.4[b]	4.44[ac]	3.50[c]
				F (beet pulp)	12.3 + 4.4 hay	23.1[c]	39.8[bc]	48.4[b]	4.32[c]	3.41[b]
Valk et al., 1990	83	76.1	RG	S (corn)	12.3 + 3.3 CrO[8]	24.6	40.3[a]	62.5[a]	3.92	3.48
(confinement)[6]				F (beet pulp)	11.9 + 3.3 CrO[8]	24.9	38.9[b]	56.8[b]	4.15	3.43

[a,b,c]Means within reference with different superscripts differ ($P < 0.05$).
*Adapted from Bargo et al., 2003.
[1]Pre-experimental DIM and milk production (lb/day).
[2]0G = orchardgrass; RG = perennial ryegrass.
[3]Between parentheses main starch or fiber source in the concentrate.
[4]Not available.
[5]Organic matter intake.
[6]In confinement studies, fresh cut-forage was used instead of grazed pasture.
[7]Level of mineral added.
[8]Chromic oxide pellets.

Table 5. Effect of amount of concentrate supplementation on DMI, milk production and composition of dairy cows on pasture.*

	Cows[1]				-------------------- DMI, lb/d --------------------			Milk	Fat	Prot.
Reference	DIM	Milk	Pasture[2]	Source[3]	Amount	Pasture	Total	Lb/d	%	%
Arriaga-Jordan & Holmes, 1986[4]	72	83.2	RG (rotat'l)	Barley	1.5	33.7	35.2	64.5	3.73^{a}	NA
					10.3	32.3	42.7	70.2	3.51^{a}	NA
			RG (cont.)	Barley	1.5	39.8	41.4	66.4^{a}	3.64^{a}	NA
					10.3	36.3	46.6	32.8^{b}	3.40^{b}	NA
Bargo et al., 2002a	101	100.8	OG (lo allow)	Min/vit	1.8	38.5^{b}	40.3^{a}	42.0^{a}	3.82^{a}	2.98^{a}
				Corn	18.9	34.1^{a}	53.0^{c}	65.3^{c}	3.29^{b}	3.08^{b}
			OG (hi allow)	Min/vit	1.5	45.1^{c}	46.6^{b}	48.8^{b}	3.79^{a}	2.93^{a}
				Corn	19.1	32.2^{a}	54.6^{c}	65.8^{c}	3.32^{b}	3.11^{b}
Hoden et al., 1991	49	66.4	RG	Corn/beet pulp	1.1	NA	NA	45.5^{a}	3.78	3.03^{a}
					8.1	NA	NA	49.7^{b}	3.76	3.09^{b}
Dillon et al., 1997	31	52.8	RG	Corn/beet pulp	0.0	37.6	37.6^{a}	52.8^{a}	3.71	3.25
					4.0	36.3	40.3^{b}	55.0^{b}	3.68	3.28
					7.9	37.0	44.9^{c}	58.5^{c}	3.55	3.26
Reis & Combs, 2002b	84	91.5	A/RC/RG	Corn	0.0	30.6^{a}	30.6^{a}	48.0^{a}	3.89^{a}	2.85^{a}
					11.0	27.9^{b}	38.9^{b}	59.0^{b}	3.50^{b}	2.95^{b}
					22.0	21.6^{c}	43.6^{c}	66.9^{c}	3.08c	3.05^{c}
Robaina et al., 1998	180	47.0	RG/WC	Barley	0.0	31.5^{a}	31.5^{a}	28.4^{a}	4.33	3.10^{a}
					4.0	29.7^{b}	33.7^{b}	34.5^{b}	4.33	3.19^{b}
					7.5	26.6^{c}	34.1^{c}	35.4^{c}	4.36	3.17^{b}
					14.7	22.9^{d}	37.6^{d}	40.5^{d}	4.36	3.29^{b}
Sayers, 1999	40	Not Avail.	RG	Bar/Wht/Corn	11	12.6^{a}	38.7^{a}	68.6^{a}	3.66^{a}	3.37^{a}
					22	20.9^{b}	42.9^{b}	76.1^{b}	2.99^{b}	3.55^{b}
Walker et al., 2001	167	49.1	P/RG	Barley/Wheat	0.0	26.6^{d}	26.6^{a}	27.3^{a}	4.48^{b}	3.16
					6.6	26.4^{d}	33.0^{b}	34.3^{b}	4.21^{b}	3.33
					11.0	24.6^{c}	35.6^{c}	40.3^{c}	4.09^{b}	3.33
					15.4	23.3^{bc}	38.7^{d}	43.8^{cd}	4.05^{b}	3.30
					19.8	22.9^{b}	42.7^{e}	45.5^{d}	4.18^{b}	3.35
					22.9	20.2^{a}	43.1^{e}	48.2^{d}	3.25^{a}	3.41

^{a,b,c,d}Means within reference with different superscripts differ ($P < 0.05$).
*Adapted from Bargo et al., 2003.
1Pre-experimental DIM and milk production (lb/day).
2A = alfalfa; 0G = orchardgrass; P = paspalum; RC = red clover; RG = perennial ryegrass; WC = white clover.
3Main energy source in the concentrate.
4Organic matter intake.

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