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Protein and Carbohydrate Nutrition of High Producing Dairy Cows

This NebGuide discusses the protein and carbohydrate requirements for milk production by dairy cows, and feeding guidelines to meet those requirements.

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Crude protein makes up 14 to 19 percent, and carbohydrates 65 to 75 percent of the total ration dry matter in common dairy cow diets. As milk production per cow increases above 19,000 to 20,000 pounds per year, understanding how these nutrients are used by the dairy cow for milk production allows the formulation of diets that optimize solids-corrected milk production.

Dietary Carbohydrate Fractions

The carbohydrate fraction of the diet is divided into fiber and non-fiber components. The fiber carbohydrates, commonly called neutral detergent fiber (NDF), include lignin, cellulose, and hemicellulose. Neutral detergent fiber represents the indigestible or slowly digested components of the ration.

Non-fiber carbohydrates (NFC) are rapidly digested and include: starch, sugars and pectin. NFC is calculated as:

$$100 - (\text{NDF} + \text{Crude protein} + \text{Fat} + \text{Ash})$$

Evaluation of the total carbohydrate status of a ration should include measurements of NDF, NFC, and forage particle length. Further information on the fiber requirements of dairy cattle is found in NebGuide G90-999, *Nutritional Management of the High-Producing Dairy Cow in the 1990s*.

Dietary Crude Protein Fractions

Dietary crude protein (CP) is degraded by rumen microbes to peptides, amino acids, and ammonia, or it escapes ruminal digestion and flows to the lower tract ("escape" or "bypass" protein). The amount of protein needed to meet the needs of high producing cows may not be met solely by microbial protein from ruminal digestion.

The practice of feeding escape or "bypass" protein to dairy cows is becoming increasingly common. If fed properly, sources of escape protein may promote higher milk production. The most recent National Research Council publication on Dairy Cattle nutrition (1989) gives recommendations for ration levels of degradable intake protein (DIP) and undegradable intake protein (UIP). The term UIP refers to escape protein. *Table I* summarizes the protein and carbohydrate composition of some commonly used feedstuffs.

Table I. Carbohydrate and protein composition of selected feeds				
<i>Feed</i>	<i>NDF¹</i>	<i>NFC²</i>	<i>Crude protein</i>	<i>Protein undegradability</i>
	<i>Percent of Dry Matter</i>			<i>Fraction of CP³</i>
Concentrates				
Corn, shelled	9.0	74	10	.50
Corn, ear	25.0	60	10	.45
Sorghum	8.7	74	13	.50
Oats	32.0	47	13	.20
Wheat	12.0	73	16	.22
Forages				
Alfalfa, LV ⁴	40.0	25	20	.25-.30
Alfalfa, EB	44.0	24	18	.25-.30
Alfalfa, MB	48.0	24	17	.25-.30
Corn silage	45.0	40	8.0	.31
Byproducts				
Beet pulp	54.0	30	9.7	.40
Brewers grain, dry	46.0	14	25	.50
Cottonseed	44.0	8	23	.35
Distillers grains, dry	44.0	11	23	.55
Soybean meal	11.0	26	50	.35
Soyhulls	74.0	10	12.1	.30
¹ NDF = neutral detergent fiber. ² NFC = non-fiber carbohydrate. ³ CP = crude protein. ⁴ LV = late vegetable stage; EB = early bloom; MB = mid-bloom. Note: The fraction of CP which is rumen undegradable may be as low as 15 percent in immature alfalfa silage.				

Properly Feeding Carbohydrates and Protein

Table II presents feeding guidelines for fiber, non-fiber carbohydrates, and protein for high producing dairy cows. Note that minimum NDF levels range from 26 to 30 percent of total ration dry matter, with approximately 75 percent of this NDF coming from coarse forage (dry hay or haylage of adequate particle size).

Table II. Fiber and protein guidelines for diets of lactating dairy cows	
Fiber Analyses	Minimum fiber (percent of dry matter)
Acid detergent fiber	18 - 21
Neutral detergent fiber (NDF) ¹	26 - 30
NDF from forage	21 - 22
Forage program	Minimum percent of dry matter from forage
Corn silage (CS)	50 - 60
CS + 5 pounds baled hay	45 - 55
75:25 CS:Haylage	45 - 55
50:50 CS:Haylage	45 - 50
25:75 CS:Haylage	40 - 50
Haylage	40 - 45
	NFC (percent of dry matter)
Minimum nonfiber carbohydrate (NFC)	20 - 25
Maximum NFC	40 - 45
Crude protein²	Ration CP (percent of dry matter)
50 pounds milk	15
90 pounds milk	17
110 pounds milk	18
	Percent of crude protein
% of Crude protein as Undegraded intake protein, UIP	33 - 35
¹ Formulation of diets with NDF levels below 26 percent NDF may predispose cows to chronic feed intake fluctuations, acidosis, lameness, and milk fat depression. ² Requirements for a 1300 lb cow producing milk with a 4.0 percent fat test. Source: Carbohydrate and Protein Needs of High Producing Dairy Cows. R. Shaver and W.T. Howard, 1989. National Research Council. 1989. Nutrient Requirements of Dairy Cattle.	

Depending upon the forage feeding program, the suggested **minimum** percentage of forage in the ration dry matter ranges from 40 to 60 percent. In general, it is best to limit corn silage to 50 percent of forage dry matter, if possible.

Non-fiber carbohydrate levels in the total ration dry matter should not fall below 20 to 25 percent, nor

go above 40 to 45 percent (*Table II*). Rations formulated for 35 to 37 percent NFC, dry basis, should avoid metabolic disturbances related to feeding high levels of starches in grains and concentrate mixes.

For diets high in corn silage or grain, use of high-fiber byproduct feeds may help reduce the starch load on the rumen. Byproducts such as soyhulls, wheat bran, brewers and distillers grains are low in NFC and work well in high production rations. See NebGuide G90-978, *Byproduct Feedstuffs for Beef and Dairy Cattle*, for information concerning feeding suggestions on these byproduct feeds.

For high producing cows, ration crude protein ranges from 15 to 18 percent for 1,300 pound cows producing 50 to 110 pounds of 4 percent fat-corrected milk (*Table II*). These CP percentages assume dry matter intake levels of 40 to 55 pounds per cow daily. The percentage of total crude protein which should escape rumen degradation (undegraded intake protein, UIP) is between 33 to 35 percent. Some research indicates a benefit from UIP levels as high as 40 percent.

Table III gives average nutrient composition of various soybean products commonly fed to dairy cattle. The crude protein level is higher in soybean meal compared to whole soybeans. The higher energy value of whole soybeans reflects the high fat content of beans compared to bean meal. The undegraded intake protein, that fraction which escapes rumen digestion, increases with heat treatment.

Table III. Typical nutrient composition of common soybean products fed to dairy cattle						
	<i>Soybean Product</i>					
<i>Nutrient</i>	<i>SBM¹, 48%</i>	<i>SBM, 44%</i>	<i>E-SBM², 44%</i>	<i>WSB³</i>	<i>R-WSB⁴</i>	<i>E-WSB⁵</i>
Dry matter (%)	88	90	90	90	93	93
	----- (Dry matter basis) -----					
Crude protein (%)	54.5	49	49	42	42	42
UIP ⁶ (% of crude protein)	30	30	45	20	49*	48
NE _L (Mcal/pound)	.91	.88	.89	.96	.98	.94
Fat (%)	1.0	1.5	5.3	19	20	18
Ash (%)	6.5	7.3	6.7	5.5	5.1	6.7
ADF (%)	6	10	6	10	11	10
NDF (%)	8	11	8	12	13	11
Ca (%)	.29	.30	.29	.27	.28	.29
P (%)	.70	.68	.68	.65	.66	.68
Mg (%)	.32	.30	.28	.29	.23	.28
K (%)	2.30	1.98	1.98	1.82	1.89	1.98
S (%)	.48	.37	.37	.24	.24	.37
Se (ppm)	.11	.11	.11	.12	.12	.11

¹SBM = soybean meal. ²E-SBM = expeller soybean meal. ³WSB = raw whole soybeans. ⁴R-WSB = roasted whole soybeans. ⁵E-WSB = extruded whole soybeans. ⁶UIP = undegraded intake protein.

***Note: Fraction of undegraded crude protein of heated soybeans can vary widely depending on time and temperature of heating and postheating holding method.**

Since heat-treated soybean products have higher escape or "bypass" protein value, they are used increasingly in high milk production rations; especially those rations formulated for greater than 19,000 to 20,000 pounds of milk per cow per year. It is important to note, however, that the fraction of undegraded crude protein of heated soybeans *can vary widely* depending on time and temperature of heating, and postheating holding method.

Other sources of escape protein include distillers dried grains, brewers dried grains, and animal byproducts such as blood meal, fish meal, and bone meal.

Evaluating Rations for Escape Protein and Non-Fiber Carbohydrates

Tables IV and V illustrate an example of how to evaluate rations for adequacy of escape protein and NFC. By knowing the pounds of dry matter consumed for each ingredient, and the crude protein, NFC, and UIP percentages of each ration ingredient, the total ration levels of each of these nutrients can be determined. Currently, most computer ration formulation software is unable to check rations for NFC or escape protein levels, but it is worthwhile to compare the hand-calculated levels in your ration to the suggested guidelines in this NebGuide.

Table IV. Calculation of escape protein levels for an example ration for cow producing 110 pounds of 3.8 percent fat-corrected milk.

<i>Feed</i>	<i>Dry matter (pounds) X</i>	<i>Crude protein (percent of dry matter) =</i>	<i>Crude protein (pounds) X</i>	<i>Fraction of undegraded crude protein =</i>	<i>Undegraded Crude protein (pounds)</i>
Corn silage	5	9	.45	.31	.14
Alfalfa hay	2	19	.38	.28	.11
Alfalfa silage	15	21	3.15	.25	.79
Shelled corn	18	10	1.8	.50	.90
Soybean meal, 44%	4	50	2.0	.35	.70
Distillers dried grains	4	23	.92	.55	.51
Minerals/Vitamins	.7	–	–	–	–
Total diet	48.7		8.7 pounds (17.8 percent crude protein)		3.15 pounds (36 percent UIP as percent of CP ¹)

¹UIP = undegraded intake protein.
CP = crude protein.

Conclusions

To optimize solids-corrected milk production, a ration should be balanced for NDF, NFC, crude protein,

and escape protein. This is an active area of research, and guidelines may change as more research data becomes available. The guidelines given in this NebGuide are the best current recommendations for meeting the total carbohydrate and protein requirements of lactating dairy cows.

Table V. Calculation of non-fiber carbohydrate levels for an example ration for cow producing 110 pounds of 3.8 percent fat-corrected milk.			
Feed	Dry matter (pounds) X	Non-fiber carbohydrate (percent of dry matter) =	Non-fiber carbohydrate (pounds)
Corn silage	5	40	.45
Alfalfa hay	2	24	.48
Alfalfa silage	15	25	3.75
Shelled corn	18	74	13.32
Soybean meal, 44 percent	4	26	1.04
Distillers dried grains	4	11	.44
Minerals/Vitamins	.7	—	—
Total diet	48.7		19.48 pounds (40 percent non-fiber carbohydrate)

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