RATION FORMULATION BASED ON TOTAL NUTRIENT COMPOSITION OF FEEDS

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ABSTRACT

Dairy cows are the most efficient of all farm animals in converting otherwise non edible feedstuffs by man to wholesome food. Unrelenting advancements in genetic selection continue to elevate upper limits of potential milk yields. Systems to house and manage these animals are capital intense and constant pressure is in keeping cows that are individually very efficient by virtue of their production potential. The challenge to meet production goals must be effective and profitable while maintaining animal health and sound reproductive performance. Expanding our knowledge in defining nutrient composition and developing nutrition programs to permit state of the art formulations are key to the continued success for those who grow the feed as well as those who own dairy animals for the purpose of converting feed and feed by-products into food for human consumption.

Key Words: feedstuffs, production potential, nutrient composition, formulation, dairy cows

INTRODUCTION

In the United States dairymen feed approximately 10 million dairy cows. During an average day, these animals will consume roughly 174,000 tons of feed dry matter and yield about 50 million gallons of milk (1). The conversion efficiency of feed to milk is estimated to be as high as 1.4 pounds of milk per pound of dry matter intake (DMI) for high producing herds, but closer to 1.2 for the average of all producing herds. There is about a 15% difference in these conversion rates, which significantly impact profit/loss results. Part of the reason for this conversion difference is likely related to nutritional imbalances and variability in feedstuffs provided to cows in many of the herds. With unfortunate consequence, there are dairymen who do not economically or adequately monitor their feed programs which directly affects the potential and actual cow's performance. Errors in ration formulation and lack of precise nutrient composition for individual feedstuffs account for the greatest variation in nutrient intake by dairy cows. These errors can be reduced by implementation of sound feed management programs.

Provision of adequate and consistent daily amounts of required nutrients is a key to high production and efficiency by all types of livestock (2). Reduced accuracy in nutrient analyses, diet formulation, or irregular allocation of these diets can decrease performance and profit potential. For dairy cows, nutrient analyses of forage and concentrates must periodically be tested to control the variability of the feeds used. Of all feed sources, the variability in forages quality and nutrient composition has the most profound impact on milk production. The reason for this is because forage quality is influenced by numerous conditions from growing to final product. Alfalfa hay probably receives more attention that most crops due to it's magnitude of importance in dairy rations. No other feed ranks as high as a forage source yet, no other feed crop suffers a higher loss of potential nutrients from the time of harvest to the time it is fed. Consequently, more time and effort is spent in evaluating this forage than any other feedstuffs.

FORAGE QUALITY AND PERFORMANCE

Forage quality is primarily a function of nutrient density and interpretation of quality is based largely upon the management objective of what is to be expected from its use. The characteristics of a forage certainly need be different to meet the needs of a dairy cow in early lactation when compared to one in late lactation or in dry periods. In dairy cow rations, forage quality is probably best expressed with regard to it's nutritive value and its potential for allowing optimal voluntary intake. When considering nutrient requirements at a given production level, **daily nutrient intake** is key. The combination of diet nutritive content, digestibility and total daily intake of the diet are the driving force behind animal performance..

Intakes will be depressed if feeds are not acceptable (palatable), the rate of digestibility is low and/or if retention time in the digestive tract in too long. Current best efforts at predicting feed quality is by testing plant cell make-up. Plant cells are composed of cellular contents and cell walls, and the ratio of these two dictate rate of digestion (Table 1) . Cellular contents are highly digestible and are most abundant in the seeds or grain concentrates. Plant cell walls, or fiber, provide rigidity and protection for plants, thus reducing cellular content fraction . While animals themselves cannot digest the cell walls (fiber), microorganisms in the rumen can digest it partially. Thus, while important for plants, fiber of low digestibility reduces forage quality and can adversely effect production performance. Techniques that emphasize fiber fractions are the indicative of modern forage testing systems. Both neutral detergent and acid detergent are used to predict forage quality.

Table 1. Forage cell fraction and components of each derived from detergent analysis (3).

Fraction	Components	Availability
Cell contents (soluble in neutral-detergent)	Lipids Sugars, organic acids and water-soluble matter Pectin, starch Non-protein nitrogen Soluble protein	Almost completely digestible not lignified
Cell wall constituents (fiber insoluble in neutral-detergent)		
1. Soluble in acid-detergent	Hemicellulose Fiber-bound protein	Partially digestible according to the degree of lignification
2. Acid-detergent fiber	Cellulose Lignin Lignified nitrogen	

Neutral detergent dissolves cell contents, leaving the cell wall. The cell wall consists of cellulose, hemicellulose and lignin. Cellulose and hemicellulose are complex cell wall carbo- hydrates digested only by microorganisms. Lignin, an indigestible cementing material in cell walls, limits their digestion. The material not dissolved is neutral detergent fiber (NDF).

Acid detergent dissolves hemicellulose, leaving lignin and cellulose. This undissolved residue is acid detergent fiber (ADF).

Space occupied by undigested forage within the digestive tract limits intake of additional forage. Because fiber digests slowly and incompletely, high fiber concentration causes depressed intake. To date, NDF is one of the best chemical predictors of potential intake, whereas ADF is used as a predictor of digestibility.

COMMON NUTRIENT ANALYSIS PROFILE

In evaluating any feedstuff, nutrient priority focuses on energy and protein content. These two nutrients are the first limiting sources for production and most expensive. Feed testing laboratories commonly express energy values (TDN or NEl) as a part of the feed analysis report (Table 2). It is often assumed incorrectly that this value is actually determined by a laboratory procedure when, in fact, it is calculated from an empirical equation based on fiber analysis. The same is true with crude protein. This method of analysis adds utility in testing one single forage group such as alfalfa (i.e., ease, speed and feasibility), but says little in describing its nutritional and chemical uniformity nor comparability across other feed types (4).

Table 2. Commonly reported analytical results for alfalfa hay sample.

RESULTS OF ANALYSIS	AS RECEIVED	90% DRY	100% DRY	
DRY MATTER	86.9			
ACID DETERGENT FIBER (ADF)	23.4	55.9	62.1	%
TOTAL DIGESTIBLE NUTRIENTS (TDN)	54.0	55.9	62.1	%
NET ENERGY FOR LACTATION (NEl)	0.553	0.573	0.636	Mcal/#
CRUDE PROTEIN	22.0	22.8	25.3	%

NUTRIENT PROFILES FOR RATION BALANCING

Accurate ration formulation for all dairy cows (growing, lactating or dry) can only be achieved by having complete nutrient profiles on all feeds being fed (Table 3). Common feedstuffs are composed of carbohydrate, protein, fat, ash and water. Carbohydrate, protein, fat and ash are further subdivided by chemical and elemental composition. Based on experimental and analytical data, each component has unique physical characteristics, rumen degradation rates, and postruminal digestibility traits (5). Carbohydrates are partitioned into structural (SC) and non structural (NSC) fractions. Protein is described in terms of amino acids, peptides, nitrogen solubility and digestion rates. Fat is classified by source and composition. Ash or mineral is broken down to elemental composition.

In part, animals derive their minerals from the feeds they consume. Plant or feedstuffs elemental composition and concentrations are relevant to determining additional mineral requirements. Generally, soil composition and plant maturity will influence mineral analysis. The macro elements calcium, phosphorous, magnesium, iron and sulfur are most critical on short term basis, yet warrant no more attention than the micros (zinc, copper, manganese, selenium, molybdenum and cobalt) when considering animal health, reproductive efficiency and optimal production expectations. Excess or deficiencies can cause imbalances that result from negative interactions of these nutrients. The complexity of the system appears a bit extreme, yet is essential when attempting to formulate to meet exact needs of a ruminant animal.

Table 3. Nutrient display in the Net Carbohydrate and Protein System (6).

Nutrient	Unit	Nutrient	Unit
Crude protein	%DM	Calcium	%DM
Under protein	%CP	Phosphorous	%DM
Deg prot	%CP	Magnesium	%DM
Sol prot	%CP	Potassium	%DM
Bound prot	%CP	Sulfur	%DM
ME	MCal/lb	Sodium	%DM
NEI	MCal/lb	Chlorine	%DM
NEm	MCal/lb	Iron	PPM
NEg	MCal/lb	Zinc	PPM
NDF	%DM	Copper	PPM
eNDF	%NDF	Manganese	PPM
Ferm Fiber	%DM	Selenium	PPM
Ferm Fiber	%NDF	Cobalt	PPM
NSC	%DM	Iodine	PPMStarch
%DM	Molybdenum	PPM	
Ferm starch	%DM	Vitamin A	KIU/KG
Ferm starch	%Starch	Vitamin E	KIU/KG
Total Fat	%DM	Vitamin E	IU/KG
Fat 1	%DM		
Fat 2a	%DM		
Fat 2b	%DM		
Fat 3	%DM		

COMPLETE NUTRIENT PROFILE

Forages are the foundation of dairy ration formulation because they promote rumen function and are a source of essential nutrients. The framework of current feeding programs is based upon energy, fiber, protein, and mineral composition of individual feed ingredients. As mentioned earlier, cell-wall and cell wall components direct potential forage intake and the conversion efficiency by the cow. A critical interrelationship exists between energy demand, energy intake, and energy balance in all high producing dairy cows. The challenge in meeting the production goals and doing this economically can only be accomplished by have accurate nutrient profiles of the feeds being fed. Requirement guidelines are available , bur realizing projected goals requires high quality, highly digestible forages. When balancing a ration, it is important to know as much about the feed as possible. As shown in Table 4., todays forage testing laboratories are capable of much more than estimating energy and protein from a fiber fraction. Where a simple description such as TDN may be enough for pricing and marketing hay, it falls short when trying to optimize rumen fermentation and subsequent microbial protein synthesis. The responsibility of a ruminant nutritionist is to make a best effort approach in obtaining as much information as feasibly possible and create efficient and economical rations that will support todays high producing cows.

CONCLUSION

Distribution and proportion of forage, feed by-products and concentrates are critical throughout all phases of animal growth and production for both economical and herd health reasons. Quality of these feedstuffs are not totally controlled, but the means by which their nutrient composition can be determined and compared to other classes of feeds are available. It is not the responsibility of the feed producer nor is it typically practical of the dairy owner to critically analyze these feeds and attempt to interpret the data for practical application in a ration formulation. What is important is that all feedstuffs should be analyzed. This information can be utilized to not only insure greatest milk yield from a cow, but also allow growers to realize what their best efforts are producing and provide them with valuable information that may lend to enhanced crop production in terms of quality and quantity.

Table 4. Total forage nutrient profile for alfalfa hay (7).

ANALYSIS RESULTS		
Components	As sampled	Dry Matter
% Moisture	88.8	#####
% Dry matter	11.2	#####
%Crude Protein	19.7	22.2
%Available Protein	18.7	21.0
%Unavailable Protein	1.1	1.2
%Adjusted Crude Protein	19.7	22.2
%Soluble Protein		48.1
%Acid Detergent Fiber	27.0	30.4
%Neutral Detergent Fiber	33.1	37.3
%Lignin	5.1	5.7
%Crude Fat	2.1	2.4
%NSC	25.4	28.6
%TDN	57.7	65.0
Net Energy-Lactation (MCAL/LB)	0.60	0.67
Net Energy-Maintenance (MCAL/LB)	0.56	0.63
Net Energy-Gain (MCAL/LB)	0.34	0.38
%Calcium	1.08	1.21
%Phosphorus	0.36	0.41
%Magnesium	0.31	0.35
%Potassium	2.15	2.42
%Sodium	0.06	0.071
%Sulfur	.28	.31
PPM Iron	258	290
PPM Zinc	33.7	38
PPM Copper	8.88	10
PPM Manganese	42.6	48
PPM Molybdenum	2.49	2.8
pH	5.8	
Relative Feed Value		163

REFERENCE

1 Buckmaster, D. R., and Muller, L. D. 1994. Uncertainty in nutritive measures of mixed livestock rations. J. Dairy Sci. 77:3716

2 Linn, J.G. 1992. Coping with changing feed quality. p.318. in Large Dairy Management. H.H. Van Horn and C.J. Wilcox, ed. ADSA, Champaign, IL.

3 Van Soest, P.J. 1982. Nutritional ecology of the ruminant. O & B Books, Inc. Corvalis, Or. 82 pp.

4 Mertens, D.R. 1995. Fiber evaluation and utilization for dairy cattle feeding programs. p. 105-122. in California Animal Nutrition Conference., Fresno, Ca.

5 Mertens, D.R. 1994.Regulation of forage intake. p.450-493. in G.C. Fahey Jr. and M. Collins (eds). Forage quality, evaluation and utilization. Amer. Soc. Agron., Madision, WI.

6 Sniffen, C.J., P.J. Van Soest, D.G. Fox, J.D. O'Connor, and J. Russell. 1992. A net carbohydrate and protein system for evaluating cattle diets: II. Carbohydrate and protein avaliability. J. Anim. Sci. 70:3562.

7 DHI Forage testing laboratory, 1995. Northeast DHIA, Ithaca, New York