Competition of Urea With Oilseed Proteins[1]

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ABSTRACT

Competition of urea with oilseed proteins in ruminant feeding depends primarily on economic relationships between these ingredients, cost of energy sources and proper feed formulation. A general summary of the more important factors to consider in replacing protein with nonprotein nitrogen in ruminant feeds is presented. Estimated urea utilization in the U.S. grew at a 15.5% compound annual rate from 1962 to 1966. From 1966-1969, usage increased at a 5% compound annual rate. Approximately 650,000 tons of urea were used by the U.S. Feed industry in 1969. Urea usage is expected to continue to grow in the United States. The high cost of energy sources in Western Europe will tend to slow its use by the feed industry of that area. In general, competition of urea with oilseed proteins will be greatest with heavy grain feeding of cattle, low cost grains and high priced oilseed meals.

INTRODUCTION

The competition of urea and other nonprotein nitrogen sources with oilseed proteins results from the indirect utilization of chemical sources of nitrogen by ruminant animals. These same forms of nitrogen are not utilized by nonruminant animals which require dietary sources of protein or amino acids for their well being.

In animals with a simple stomach, preformed proteins or amino acids pass directly into the stomach when food is eaten; digestive processes are initiated at this point continuing into the small intestine where further digestion and absorption of nutrients takes place. In the ruminant animal, food enters the rumen and reticulum where conditions are ideal for fermentation of food by microorganisms, some of which have the ability to transpose simple forms of nitrogen into complex proteins which are subsequently digested and absorbed in the small intestine.

It is neither necessary or possible in this presentation to trace the historical background of our present knowledge of utilization of nonprotein nitrogen by ruminants. It is of interest however that Zundt in 1891 (1) suggested that the rumen microflora play a role not only in cellulose digestion but also in the utilization of nonprotein nitrogen by ruminants. Other studies conducted during the first quarter of this century provided evidence that satisfactory replacement of 30% to 40% of the protein in rations for ruminant animals can be made with urea (1). From this early beginning, extensive research has been conducted to bring our knowledge of the utilization of nonprotein nitrogen by ruminants to its present state. Extensive reviews of the utilization of nonprotein nitrogen by ruminants have been published (2-4).

The real competition between nonprotein nitrogen sources and oilseed proteins for ruminants will depend primarily on economic relationships between these feed ingredients, the cost of energy sources, and proper feed formulation.

The more important factors related to the replacement of protein by nonprotein nitrogen in formulating ruminant feeds are: age of animal, carbohydrate or energy sources, level of protein in base feed mixture, and vitamin and trace mineral fortification and sources of unidentified factors. A general summary of information on each of these factors will be presented.

AGE AND UREA UTILIZATION

At birth, the digestive tract of the ruminant appears to function like that of the simple stomached animal. The age at which the young ruminant begins to utilize nonprotein nitrogen varies depending on the diet fed, but it appears that a portion of the nitrogen requirement of young calves six to 12 weeks of age can be supplied by urea. Any significant replacement of preformed protein by urea in rations for the young animal will however reduce performance below the optimum.

INFLUENCE OF ENERGY SOURCES ON UREA UTILIZATION BY THE RUMINANT

A source of readily digestible carbohydrate in the ration appears to be a prerequisite for efficient urea utilization by the ruminant. Apparently, some carbohydrates are more valuable than others for supplementing high roughage rations containing urea. Bell and coworkers (5) compared such high carbohydrate ingredients as corn, dehydrated sweet potatoes, grain sorghum, barley, cane molasses and a combination of corn molasses and cane molasses in a low protein basal ration supplemented with urea to bring the protein content of the ration up to 11% to 12%. The supplementation with urea had little effect on digestibility of ration nutrients other than protein, which was increased in all rations. Improvement in protein digestibility was not as marked in the molasses ration. Biological studies showed that urea nitrogen was utilized with equal efficiency in rations with different cereal grains and sweet potatoes and with less efficiency in the ration containing molasses.

Other experiments (6) also serve to illustrate the general principle that rations containing cereal grains as a source of readily available energy for rumen microflora give the best results when combined with urea. The microflora in the rumen will utilize various carbohydrates as sources of energy. Rations high in sugars or complex polysaccharides as present in roughages make for inefficient utilization of urea, starch, or nonprotein nitrogen by ruminant animals. Indications are that about 1 kg of readily fermentable carbohydrate of which two thirds should be starch is needed for each 100 g of urea fed to an adapted dairy cow for maximum milk production. If the proportion of starch drops much below this level, there is a proportionate drop in milk production.

Efficiency of conversion of feed nitrogen to milk and tissue protein on high urea, high grain rations is similar to that of plant proteins which emphasizes further the critical relationship between urea and readily fermentable carbohydrates. With dairy cows, feed consumption decreases when the nonprotein nitrogen increases above .45 g/kg of body weight (7).

Not only must the proper type and quantity of carbohydrates be available for the rumen microorganisms to convert nonprotein nitrogen effectively to preformed proteins, but also the total energy of the diet must be adequate in order that maximum growth or milk production can

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prevail. Numerous studies (3,8) have demonstrated that ruminant animals fed high roughage rations, i.e., corn silage, range grazing conditions, etc. fail to perform at the maximum when fed supplements containing urea as the major source of nitrogen. When such rations are supplemented with proper types and amounts of energy sources, performance is improved.

EFFECT OF PROTEIN ON UREA UTILIZATION

The early in vitro studies of Wegner et al. (9) indicated that the amount of urea converted to protein decreased as the concentration of casein in the system was increased. Further, with fistulated animals they observed that supplementation of a ration with urea to increase its crude protein equivalent over 18% resulted in a decreased conversion of urea to protein.

Accepting the principle that efficiency of nonprotein nitrogen utilization decreases as the level of protein in the diet approaches the optimum required by the animal, we still must question whether any preformed protein is required. Studies by Virtanen (10) demonstrate that moderate milk production can result when diets containing urea and ammonium salts are fed to dairy cows as the sole sources of nitrogen. With long adaptation periods Virtanen (11) was able to show increased rates of milk production when 1.3 to 1.4 grams of urea per kilogram of body weight were fed over that when 0.27 g/kg was fed. Conrad and Hibbs (7) had previously reported that feed consumption of dairy cows declined when the nonprotein nitrogen intake from urea increases above 0.45 g/kg body weight. We must recognize however that other sources of nonprotein nitrogen may release nitrogen at a slower rate, thus potentially making possible the replacement of larger quantities of preformed protein in ruminant feeding. Biuret appears to be more palatable, equally efficacious and less toxic than urea for ruminants (12). A starch-urea product has been shown to lower rumen ammonia levels and increase microbial protein synthesis when fed to lactating dairy cows (13). The potential impact of further developments in these areas on the replacement of preformed protein in ruminant feeding by nonprotein nitrogen sources will be determined by further research.

The importance of base ration protein level on efficiency of nonprotein utilization by ruminants will vary in the different countries of the world. For example, in a barley economy the amount of protein or nonprotein nitrogen supplementation to meet the total nitrogen needs of the ruminant animal are much lower than in those countries relying primarily on corn as the cereal grain or energy source. Thus a greater replacement of oilseed meals may be possible. Further, in those countries where grazing is extensive, the ruminant animal will need energy as well as protein, and thus oilseeds may compare more favorably with nonprotein nitrogen sources. The type of commodities available for animal feeding in different countries will markedly affect the competition of oilseed proteins with urea or other sources of nonprotein nitrogen.

TABLE I

Estimated U.S. Utilization of Urea in Animal Feeds

Year	Tons of urea	Change, %
1962-63	314,000	
1963-64	350,000	+11
1964-65	375,000	+ 7
1965-66	465,000	+24
1966-67	560,000	+20
1967-68	600,000	+ 7
1968-69	620,000	+ 3
1969-70	650,000	+ 5

INFLUENCE OF VITAMIN AND MINERAL FORTIFICATION AND SOURCES OF UNIDENTIFIED FACTORS ON UREA UTILIZATION

In general, the utilization of urea or nonprotein nitrogen in ruminant rations results in significant feed formulation modifications. These formula modifications frequently result in ingredient shifts that markedly alter the total intake by the animal of vitamins, minerals and unidentified factors that are essential for the growth of rumen microorganisms. It is safe to state that many cases of ration failure have been caused by an alteration of the intake by the animal of micronutrients resulting when oilseed proteins were replaced in ruminant rations by chemical sources of nitrogen. Thus, in much early research, the substitution of nonprotein nitrogen for oilseed proteins resulted in nutritional inadequacies of rumen microorganisms, if not of the animal itself. This is not too surprising, but adequacy of micronutrients must be considered in evaluating much of the early research work on urea utilization as well as in formulating ruminant rations for the present.

Research at the Ohio Agricultural Experiment Station (14) has indicated quite clearly that by combining urea and dehydrated alfalfa meal into a pellet, a higher level of urea can be fed without causing any depression in feed intake or milk production. The pellet was composed of 66% dehydrated alfalfa meal, 31.6% urea, 2.0% monsodium phosphate and 0.4% sodium metabisulfite as a preservative. Later, sodium propionate was used to replace sodium metabisulfite. In these experiments, the daily urea intake ranged from 0.6 lb (273 g) to 0.9 lb (409 g), which is far above previously recommended levels. Apparently, if urea is properly utilized for protein syntheses in the rumen, higher levels can be fed without deleterious effects.

Sulfur must be considered in formulating rations high in urea. The effects of supplements of inorganic sulfur, or of methionine and cystine were reviewed by Loosli (3). In general, it appears that the response to supplements of inorganic sulfur or of sulfur-containing amino acids in high urea rations for ruminants will be determined by the sulfur content of the base rations. In some cases, no beneficial responses have been obtained, whereas in others sulfur-containing supplements stimulated growth. It would appear that when good quality forages are fed, the need for sulfur is less than in rations containing corn, corn silage, or poor quality roughage.

Other mineral elements that have been shown to influence in vitro nonprotein nitrogen utilization by ruminants are phosphorus, cobalt, copper, calcium, manganese, magnesium, zinc, iron and perhaps others. All of these and probably other essential elements must be considered in practical feed formulations for ruminants where nonprotein nitrogen replaces significant quantities of oilseed proteins.

Numerous studies have revealed that microorganisms cannot synthesize protein from urea efficiently unless some source of unidentified factors is present in the ration. These have been termed urea protein synthesis factors (UPF) by Beeson and coworkers (15) at Purdue University.

Variable results have been obtained in feeding experiments involving sources of unidentified factors in combination with urea and other feed ingredients. It is evident that unidentified factors are required for proper rumen microbial growth, but further work must be conducted to determine the importance of these factors in practical feeding which involves widely differing types of feed ingredients and feeding systems.

Numerous studies have shown the toxicity of urea to ruminant animals (3). In practical application, the toxic properties are most hazardous for young animals and animals that are starved or have been off feed. Precautions must be observed in assuring that urea is thoroughly and

TABLE II

Relative Cost of Urea and Soybean Meal in Central Illinois

Year	6:1 Corn-urea mix, dollars/ton	108% of Corn urea price, dollars/ton	44% Soybean meal, dollars/ton	Spread
1960	$44.30	$47.85	$60.00	$12.15
1961	46.22	49.90	66.25	17.35
1962	46.20	49.90	71.50	21.60
1963	48.28	52.15	71.50	19.35
1964	50.16	54.15	69.50	15.35
1965	49.82	53.80	80.50	26.70
1966	50.80	54.85	79.50	24.65
1967	44.30	47.85	76.50	28.65
1968	43.67	47.15	75.25	28.10
1969	44.96	48.55	78.30	29.75

uniformly mixed into the ration.

We can conclude that urea can be efficiently and safely used in ruminant feeding. Evidence to date indicates that not more than 33% of the nitrogen required by the ruminant should be from nonprotein nitrogen. Now we will consider the impact of this level of substitution on oilseed protein usage.

Because of improper urea usage and slow development of formulation principles utilizing urea, it was about 1950 before urea was used in livestock feeds on a commercial scale. Accurate information on the amount of urea utilized for livestock feeds is extremely difficult to secure. The fact that fertilizer grade urea can also be used for feed makes it difficult to determine how much is accounted for by each of the two uses. Consequently, at the present time, we have only estimates on the amount of urea used in livestock feeds. We are hopeful that a current USDA survey of the feed industry will provide better data on urea use. The USDA has estimated United States urea usage in livestock feeds from a survey of cattle feeders and from surveys conducted by the American Feed Manufacturers Association. These data are given in Table I.

This Table shows estimates of United States utilization of urea in animal feeds during the period of 1962-69. The utilization of urea grew at a compound annual rate of 15.5% between 1962 and 1966. During this same time span, the use of natural proteins in animal feeds increased by only 2.3% per year. Urea usage increased at a compound rate of approximately 5% during the period 1966 to 1969. The usage of natural proteins in the United States grew at a rate of approximately 6% during the 1966 to 1969 period. These data indicate that the usage of urea in feeds is continuing to increase but at a much slower rate than during the early part of the 1960's. Converting the 650,000 tons of urea used in 1969-70 to soybean meal equivalent, indicates the magnitude of importance of urea to the United States feed industry and to the world oilseed protein situation. If we assume that the nitrogen from urea has a relative efficiency of 92% of that of soybean meal, the 650,000 tons utilized in 1969-70 was equivalent to 3,485,000 tons of 44% soybean meal. This would be approximately one fourth of the equivalent protein supplied by soybean meal in the United States in 1969.

The question is often raised how a synthetic product could capture such a large share of the market in a country like the United States with ample land resources and ability to produce oilseed proteins. We feel that there are three reasons which are responsible for this development: first, of course, is economics or the relative cost of protein and energy from a urea-feed grain mix compared to oilseed proteins; second, is the increased sophistication of United States livestock producers and the United States mixed feed industry; and third, is the tremendous growth in beef cattle feeding and particularly the trend toward an increased portion of cattle being fed in commercial feedlots. There is a general rule of thumb that 1 lb of urea and 6 lb of corn are roughly equivalent to 7 lb of soybean meal in energy and protein. Because of greater protein efficiency, most nutritionists maintain that soybean meal is worth approximately 8% more than the corn-urea mix.

Table II shows the annual average cost of a corn-urea mixture and 44% soybean meal in dollars per ton and the relative spread of the cost of soybean meal over a 6:1 corn-urea mix. These data are based on Central Illinois prices and the price spread obviously could be wider or narrower in other areas of the country.

The cost advantage of urea has been the primary factor responsible for the growth in urea usage in the United States. During the past 10 years, the use of urea has given livestock producers savings of 25% to 40% from the cost of oilseed proteins. Even with the current high price level of feed grains, the spread between 44% soybean meal and a corn-urea mix was about $21 per ton in the early part of September 1970. Thus, protein from urea is about 25% cheaper than oilseed proteins.

The trends toward increased grain-fed beef production and development of large commercial livestock enterprises have created an atmosphere conducive to increased urea usage. With these trends have come an increasing sophistication in feeding practices and greater attention to cost control. These factors will likely encourage additional emphasis on the use of urea in livestock feeds over the next decade.

In most other major livestock producing countries, the use of urea is not as advanced as in the United States. In major beef producing countries such as Argentina, Brazil, Australia, New Zealand and Uraguay, virtually all the beef is grass fattened rather than grain fed. In the Common Market countries of Western Europe relatively high priced feed grains reduce the cost advantage which urea has over oilseed proteins in the United States. In the Common Market countries, a corn-urea mixture would be approximately the same price per ton as 44% soybean meal. Thus, there is little economic incentive for the use of urea in the major livestock producing countries of Western Europe.

Looking to the future, urea use in the United States is expected to show continued growth. United States urea usage in projected to grow at a compound annual rate of 5% to 7% per year over the next decade. Oilseed protein usage in the United States is projected to increase at a rate of 3.5% to 4% per year during this same period. Thus urea is expected to continue displacing oilseed proteins in feeds for ruminant animals in the United States. Currently there appears to be a swing away from high urea content feeds for high producing dairy animals. It is difficult to get a heavy producing dairy cow to eat enough feed where urea makes up a significant portion of the protein in the ration. Unless this feed intake problem can be solved, it will limit increased use of urea in dairy rations.

Growth in urea usage outside the United States will be influenced by the extent of development of grain feeding of beef and dairy cattle, developments in the prices of feed grains, and world oilseed protein prices. It is likely that urea usage will not increase significantly in Western Europe as long as the Common Market agricultural policy maintains high prices for feed grains.

Urea will continue to be a strong competitor for oilseed proteins particularly in the United States. It will probably become a more important competitor in countries such as Canada, Japan, Brazil and the eastern block countries of Yugoslovia, Hungary, Czechoslovakia and Poland.

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