## Protein Nutrition Research at the U.S. Dairy Forage Research Center

Forages help meet the protein requirements of dairy cows by providing N as ruminally degraded protein for microbial protein formation plus protein that escapes degradation in the rumen. Evidence from many feeding studies with lactating cows indicates that too much protein in legume and grass forages is lost in the rumen. This problem has two major ramifications: 1) the cost of supplemental protein to compensate for the high ruminal losses of forage protein; and 2) excessive N excretion from the cow that contributes to N pollution of surface and groundwater. A number of projects at the Dairy Forage Center are addressing this problem.

### Reducing Nonprotein N in Silages Will Improve Their Protein Value

Ensiling negatively affects the quality of the crude protein in forage. During ensiling, plant cells are lysed, releasing enzymes that break down proteins into nonprotein nitrogen (NPN). In alfalfa, the principal forage grown in the northern U.S., NPN typically accounts for 50 to 65% of silage crude protein. This loss of true protein reduces N utilization by the cow. Feeding trials at the Center's Research Farm demonstrated that cows fed alfalfa silage with lower NPN and higher true protein produced more milk and protein than cows fed alfalfa silage with more NPN, even though crude protein content of both diets was equal. More of the dietary N went into milk and less went into manure. Reducing N loss in manure would be environmentally friendly, but the farmer also has an economic incentive for improving N efficiency. An analysis using DAFOSYM, the Center's whole-farm economic model, indicated that an average dairy farm in the northern U.S. loses up to $28/acre each year from breakdown of alfalfa protein in the silo. Figure 1 shows the NPN content of silages made from several legume forages. Of the legumes tested, alfalfa had the worst problem with NPN. Legumes containing tannins had reduced silage NPN; the reduction was related directly to tannin level. Of the forages without tannins, cicer milkvetch and particularly red clover had lower NPN; apparently these forages have alternative mechanisms to reduce silage NPN.

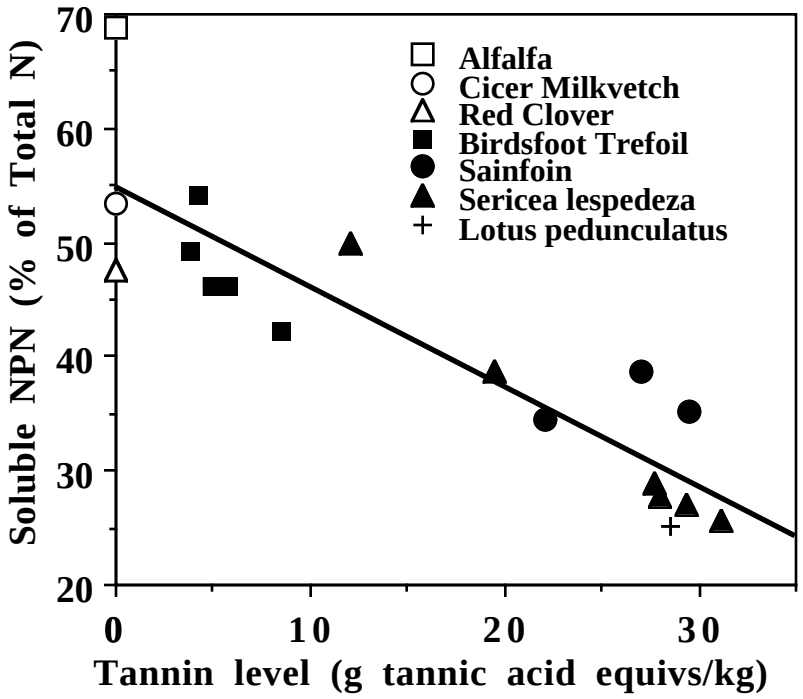



*Figure 1. Soluble nonprotein N (NPN) content of silages made from legumes with varying tannin contents.*

### An Unusual Enzyme in Red Clover Improves Its Protein Value

Red clover, a forage with similar protein content to alfalfa, forms up to 90% less NPN than alfalfa during ensiling. This suggests that red clover is a better legume to ensile. Yet the widespread use of red clover is limited by its lower yield, low field stand persistency, and slow drying rate in the field. Research was undertaken on red clover to determine the mechanism for its lower proteolysis during ensiling. Proteolysis was measured as free amino acid release in soluble extracts from alfalfa and red clover (Figure 2). After 4 hours, proteolysis was six times greater in alfalfa extract than in red clover extract; mixing alfalfa and red clover extracts resulted in proteolysis about equal to red clover alone. Boiling (which destroys enzymes) the red clover extract before adding it to alfalfa extract actually increased proteolysis over alfalfa alone. Adding ascorbate, which interferes with the action of polyphenol oxidase (PPO), increased red clover proteolysis to about 40% of alfalfa. Red clover contains several phenols, including caffeic acid, that PPO uses to form quinones; quinones react very rapidly with proteases, the enzymes that break down proteins.

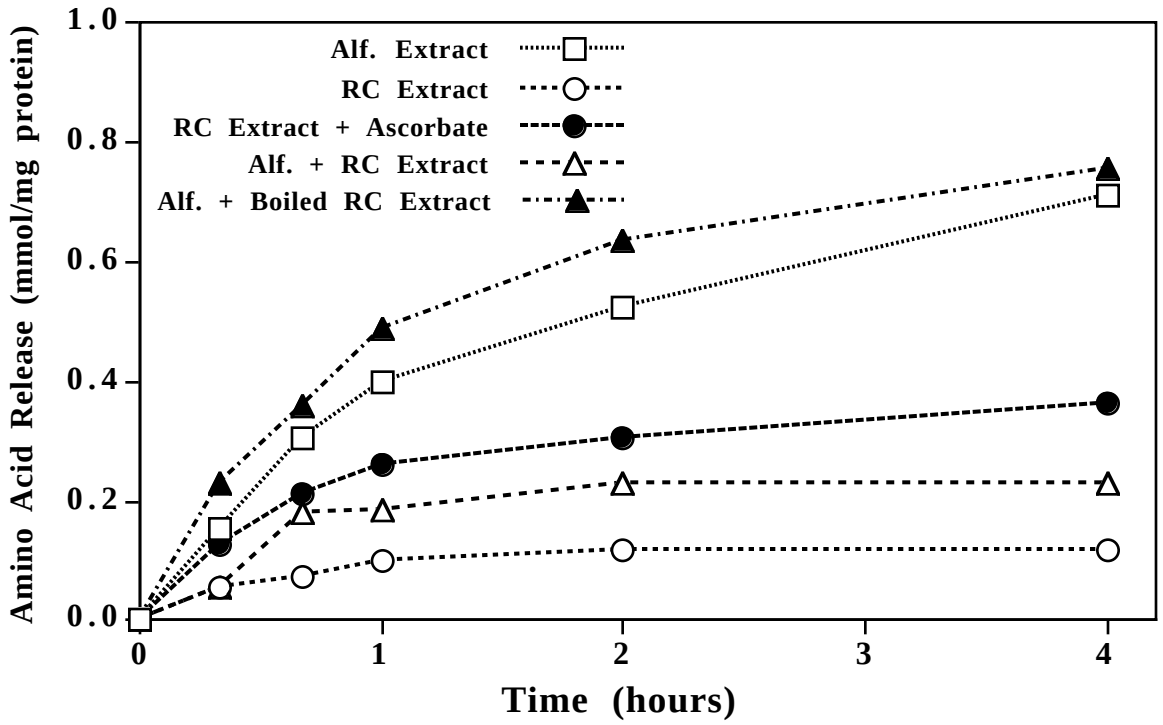



*Figure 2. Proteolysis in extracts from alfalfa (Alf.) and red clover (RC) forages.*

During incubation with red clover extracts, caffeic acid and two other as yet unidentified phenols decrease along with the decrease in proteolytic activity. These and other findings proved that the reduced proteolysis in red clover is not due to inherent differences in proteolytic activity between red clover and alfalfa but occurs because the PPO in red clover produces quinones that react with the proteases.

**Alfalfa Hay Has Greater Protein Value Than Alfalfa Silage**

Lower NPN content of alfalfa hay makes it a better protein source for the cow than alfalfa silage. Lactating cows were fed all their forage as either silage or alfalfa hay in two studies at the Center's Research Farm. Alfalfa was harvested from alternate windrows as either silage with 40% DM or as hay in small bales. Silage averaged 20.6% crude protein and hay 18.1% crude protein. Alfalfa hay had lower protein because of greater leaf loss during harvest. The NPN contents were 52% (silage) and 8% (hay) of total N. Diets contained an average (DM basis) 67% alfalfa, 32% high moisture ear corn, and 1% minerals and vitamins. Two diets were supplemented with 3% fish meal; greater milk and protein yield with fish meal would mean that the diet without fish meal had a lower protein value. Yields of milk, protein and solids-not-fat were higher on alfalfa hay than on silage

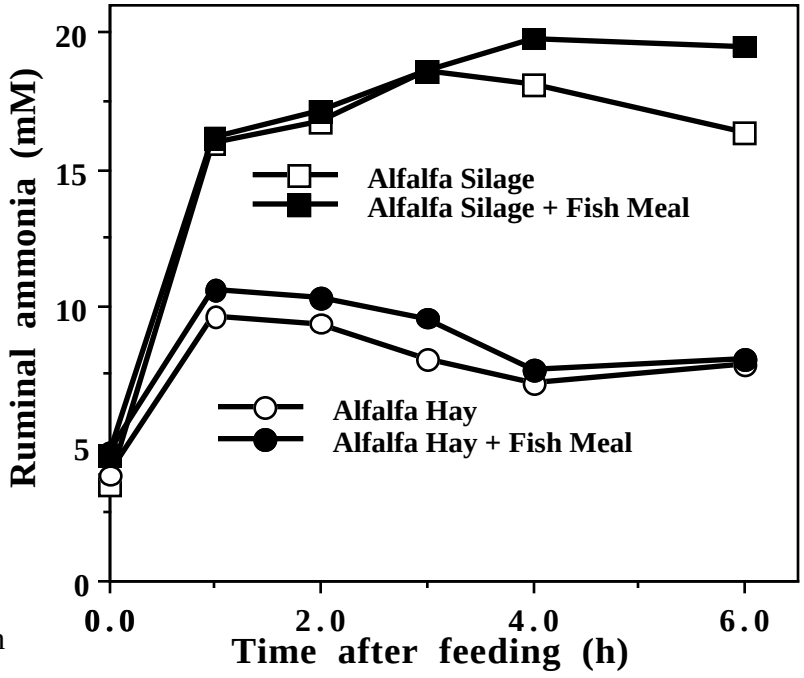
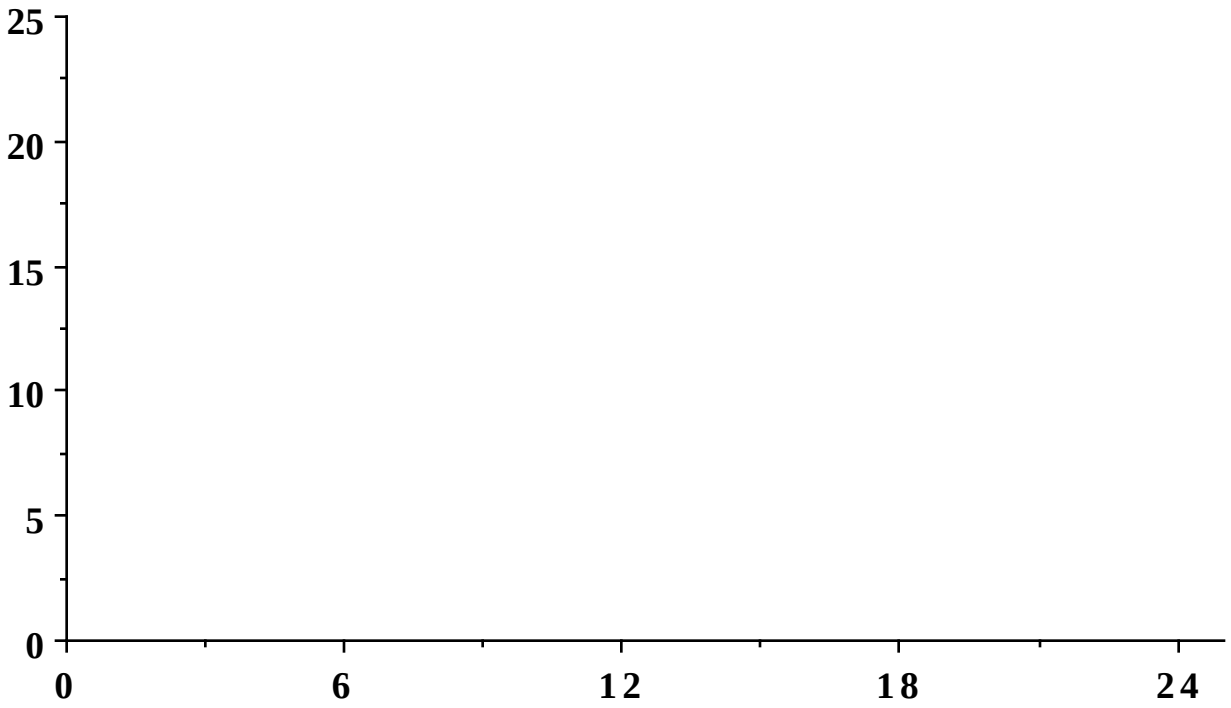



*Figure 3. Ruminal ammonia levels in dairy cows fed all their forage as either alfalfa silage or alfalfa hay, with or without supplemental fish meal.*

without fish meal. Feeding fish meal increased milk and protein yield 2.1 kg/d (4.5 lbs/d) and 100 g/d on silage and .8 kg/d and 30 g/d on hay. Digestibility of DM in silage was greater than hay; this may be why there was increased milk yield after correction of protein inadequacy by adding fish meal. Ruminal ammonia, a good index of excessive breakdown of dietary crude protein (Figure 3), clearly was greater at all times after feeding silage, averaging 15.4 mM (silage) and 8.1 (hay). Some in vitro results not shown here indicated that the ruminal microbes made more protein out of the degraded protein in hay than in silage. New developments in mechanization may improve hay harvesting. Koegel and his colleagues in the Center's engineering group have developed an alternative hay-making process involving extensive shredding of the forage prior to forming it into thin forage mats and field-drying. Drying time for the shredded alfalfa was only one-third that for conventionally harvested alfalfa hay. The energy and protein values of the shredded hay also were greater.

**Grain Processing to Improve Ruminal Microbial Protein Formation**

Yet another approach to the problem of excess NPN in alfalfa silage is enhancing N capture for ruminal microbial protein. Grinding corn to particle sizes of 600 to 700 microns improves ruminal digestion, thus promoting microbial growth and utilization of degraded protein and NPN. Some experiments at the Center demonstrated that grinding of high moisture corn through a 3/8" screen depressed ruminal ammonia (Figure 4), a measure of excessive protein degradation, and improved milk yield by 2.0 kg/day (4.4 lbs/d) over feeding the same amount of unground high moisture corn. In vitro tests with this and more finely ground high moisture corn indicated that finer grinds would not further increase microbial protein synthesis. Studies are continuing to see how much the protein supplement can be reduced by finely grinding the corn.



about 30 to 35% of the protein will escape degradation in the rumen. With soybeans, only about 25% escapes. Heat treatment can increase ruminal escape for soybeans to 50 to 60%. Research at the Center has provided the information needed to optimize the heat treatment of full fat soybeans and, further, has demonstrated the milk production response that can be obtained with properly heated soybeans. Figure 5 illustrates the improvement obtained when conventional soybean meal, unheated (Raw) soybeans and "properly" roasted soybeans were fed to lactating cows. Feeding roasted soybeans improved milk yield an average of 4 kg/day (9 lbs/day) compared to feeding the same amount of protein as soybean meal or unheated soybeans. Protein dispersibility index (PDI), an existing test for estimating extent of heat exposure, was standardized in laboratory and animal studies at the Center using numerous batches of roasted soybeans, from raw to extensively overheated. The PDI test, properly standardized for roasted soybeans, is now used in commercial labs for assessing the quality of heated soybeans. The availability of properly roasted soybeans and a test to assure their quality, have been instrumental in the growth of heat processing of soybeans for feeding to dairy cows in the U.S. from negligible amounts in 1985 to current usage of approximately 20 million bushels per year.

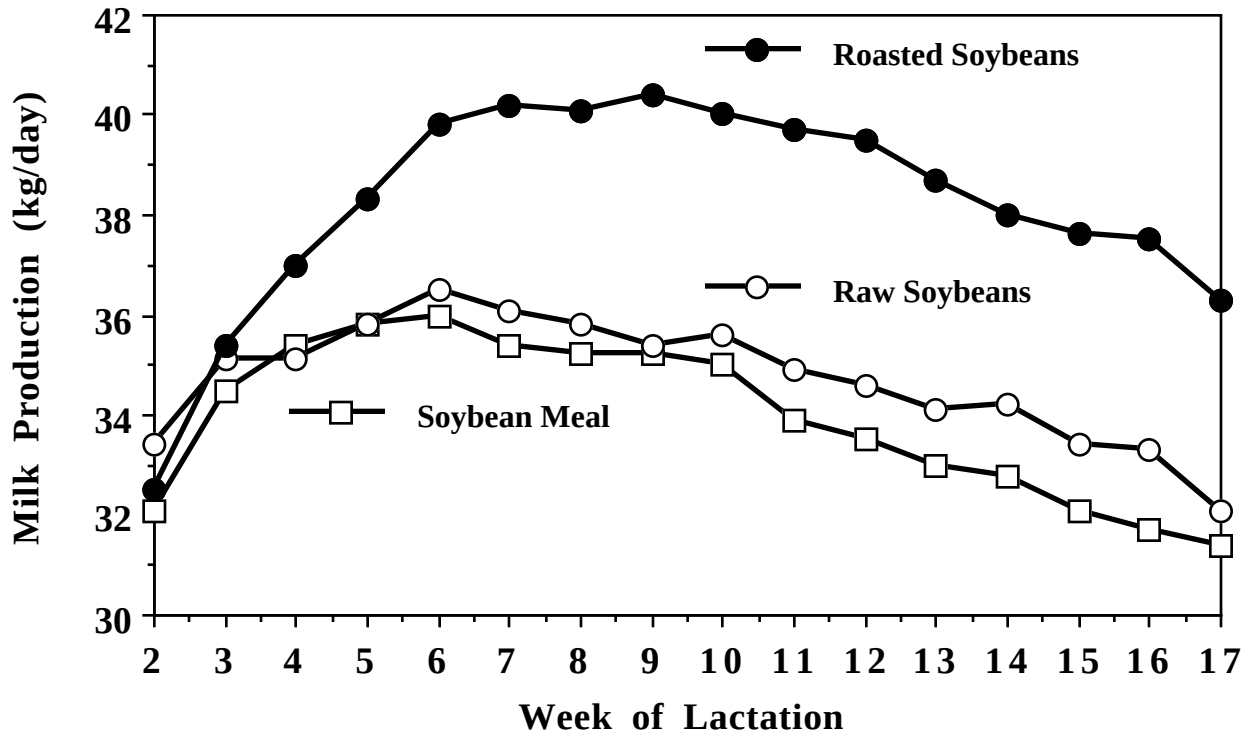



*Figure 5. Milk yield with feeding equal amounts of supplemental protein as soybean meal, unheated (raw) soybeans or "properly" roasted soybeans to lactating cows.*

**Protein Nutrition Research and the Mission of the Center**

The mission of the U.S. Dairy Forage Research Center is to apply the tools of basic and applied science to improving forage utilization by dairy cows. Forages are one of the principal protein sources in dairy cattle rations. Excess ruminal degradation of forage protein makes protein the nutritional factor that most limits the value of high quality forages by lactating cows. The Center's continuing work on protein nutrition is finding ways to improve utilization of forage protein and is putting the tools to accomplish this task into the hands of the Nation's dairy farmers.