FULL FAT SOYBEAN USE IN RUMINANTS

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INTRODUCTION

Full fat soybeans are a potentially useful, cost effective feed ingredient for cattle and sheep. Whole soybeans contain approximately 38% crude protein and 17% fat (as fed basis). The protein is considered to be of high quality and the high fat content is attractive because of its ability to increase the energy density of the diet for animals having high energy requirements. Because fat is 2.25 times higher in energy than starch, supplementation of fat via full fat soybeans allows the feeding of diets with higher energy density without reducing forage intake and increasing fermentable carbohydrates. This may help alleviate some problems associated with feeding excessive fermentable carbohydrates to dairy cows such as ruminal lactic acidosis and milk fat depression. However, inordinate feeding of unprocessed soybeans may depress ruminal fiber digestion and induce milk fat depression. This problem may be avoided by feeding limited levels of fat.

In addition to the possible energy effect provided by full fat soybeans is the potential for improving protein supply to the animal. Heat processing of whole soybeans reduces ruminal degradation by the microorganisms resulting in improved amino acid supply to the animal. In addition, heat processing destroys the trypsin inhibitor and reduces urease and lipase activity. These actions increase protein digestion and the ability to feed soybeans with nonprotein nitrogen and result in better storage properties. The final decision to feeding raw soybeans vs heat processed soybeans should be based on economics, taking into consideration the additional cost of heat processing and the return in production.

FULL FAT SOYBEANS AS A PROTEIN SOURCE FOR RUMINANTS

Protein Metabolism in Ruminants

Ruminants derive their intestinal protein supply from dietary protein which escapes ruminal degradation and microbial protein which is synthesized in the rumen (Figure 1). The combination of amino acids derived from these two sources constitutes the total supply to the animal. While microbial protein alone may be adequate for low producing ruminants, it is inadequate for supporting higher levels of growth, wool or milk production. Medium to high producing ruminants rely on some dietary protein escaping degradation in the rumen and as production levels increase, so must the supply of dietary protein escaping ruminal degradation.

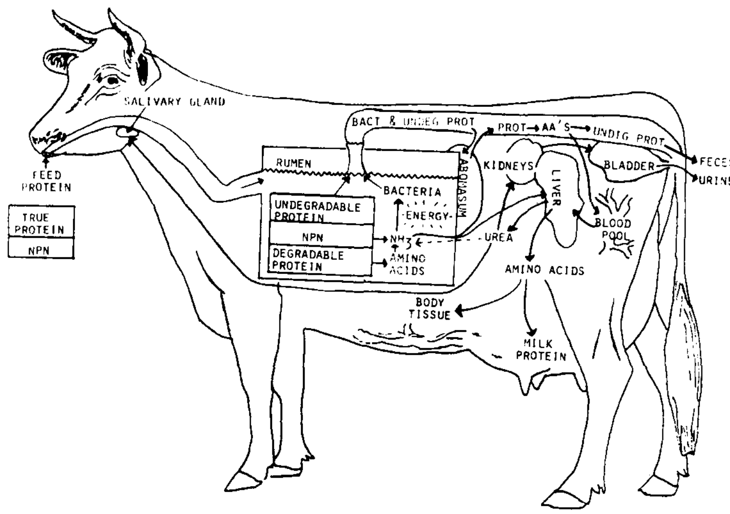

Figure 1. Schematic summary of protein metabolism in the lactating cow.

Protein Protection from Ruminal Degradation

The use of low degradable or protected proteins in diets fed to ruminants with high protein requirements improves the amino acid supply to the animal and concurrently decreases the surplus of ammonia, thereby reducing stress on liver metabolism (Kaufmann and Lupping, 1982). However, the fact that protein passes through the rumen undegraded and reaches the small intestine for digestion does not necessarily mean that it is digested efficiently, nor once digested, that the amino acid profile is such that it provides a better balance of amino acids for milk production and growth. Protecting protein from microbial degradation in the rumen will only be successful in affecting animal performance if 1) proteins are not denatured to the extent that intestinal absorption of amino acids is diminished so that the net effect on amino acid supply is reduced and 2) the animal has the metabolic capacity to respond to an increase of amino acid supply; that is requirements for amino acids have not been met (Oldham and Tamminga, 1980).

Protection methods. The most commonly used method to increase the resistance of protein to microbial degradation in the rumen is heat treatment. Many feed processing methods either require or generate heat which will reduce protein degradation in the rumen. Pelleting and extruding of soybeans appear to protect protein through the heat generated in the die. Heat treatment during solvent or pressure extraction of soybean oil seeds also decreases ruminal protein degradation as could roasters such as the Roast-a-Tron, Jet Sploder and Gem Roaster which differ greatly in processing temperatures and heating times. Although it is important that appropriate temperature and heating time should be employed for particular feeds, optimal conditions are often not known. Heating above the optimal temperature may overprotect the soybean protein, rendering it unfermentable in the rumen and indigestible in the small intestine.

The amount of overprotection is due to heat damage. Heating facilitates the Maillard reaction between primary amines and reducing sugars to yield an amino-sugar complex. These linkages are more resistant than normal peptides to enzymatic hydrolysis. Reversibility of this reaction is dependent upon temperature and time of heat exposure. Cleale et al. (1987) showed that intermediates of the Maillard reaction via controlled non-enzymatic browning may be effective in reducing ruminal degradation of soybean protein without overprotecting it.

In addition to heat, other treatments have been successful in decreasing degradability of soybean protein in the rumen. These include the use of aldehydes such as formaldehyde, glutaraldehyde and glyoxol, sodium bentonite, sodium hydroxide, alcohol, blood, fish hydrolysate, propionic acid and calcium lignosulfonate. Waltz and Stern (unpublished data) used the in situ procedure to evaluate the effect of various protection methods on ruminal degradability of soybean meal protein (Figure 2). They found that expeller processing, calcium lignosulfonate treatment and formaldehyde treatment of soybean meal were most effective in reducing ruminal protein degradation. These results are consistent with the findings of Waltz and Stern (1987) who used continuous culture to evaluate the same protection methods.

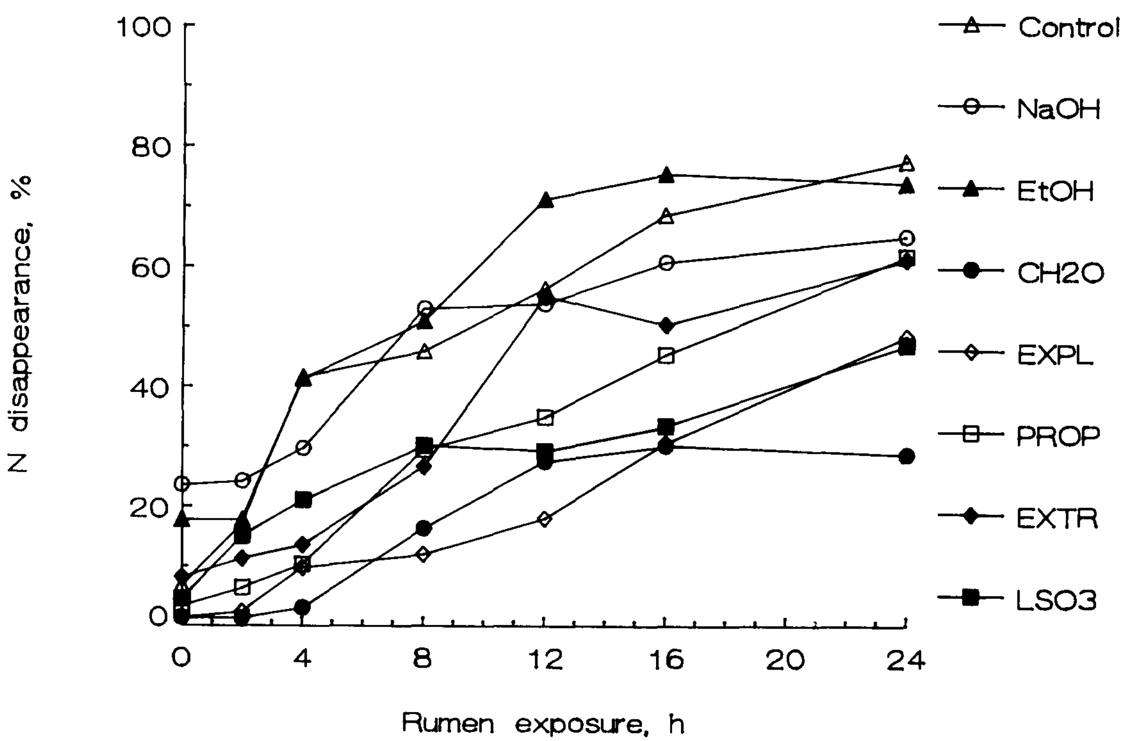

Figure 2. Nitrogen disappearance from dacron bags containing SBM (control), sodium hydroxide treated SBM (NaOH), ethanol treated SBM (EtOH), formaldehyde treated SBM (CH_2O), expeller processed SBM (EXPL), propionic acid treated SBM (PROP), extruded SBM (EXTR) and calcium lignosulfonate treated SBM (LSO_3).

Ruminal Protein Degradation and Intestinal Amino Acid Supply of Full Fat Soybeans

The effect of extruding whole soybeans at 132 and 149°C compared to soybean meal and raw soybeans on ruminal protein degradability measured in situ is shown in Figure 3 (Stern et al., 1985). Raw soybeans were clearly more degradable than the extruded soybeans or soybean meal at all intervals of rumen exposure. At 1 hour of ruminal exposure time, soybean meal and the two extruded soybean products appeared to be similar in readily available or soluble nitrogen. However, as time in the rumen increased, the extruded soybeans were more resistant to microbial degradation than soybean meal.

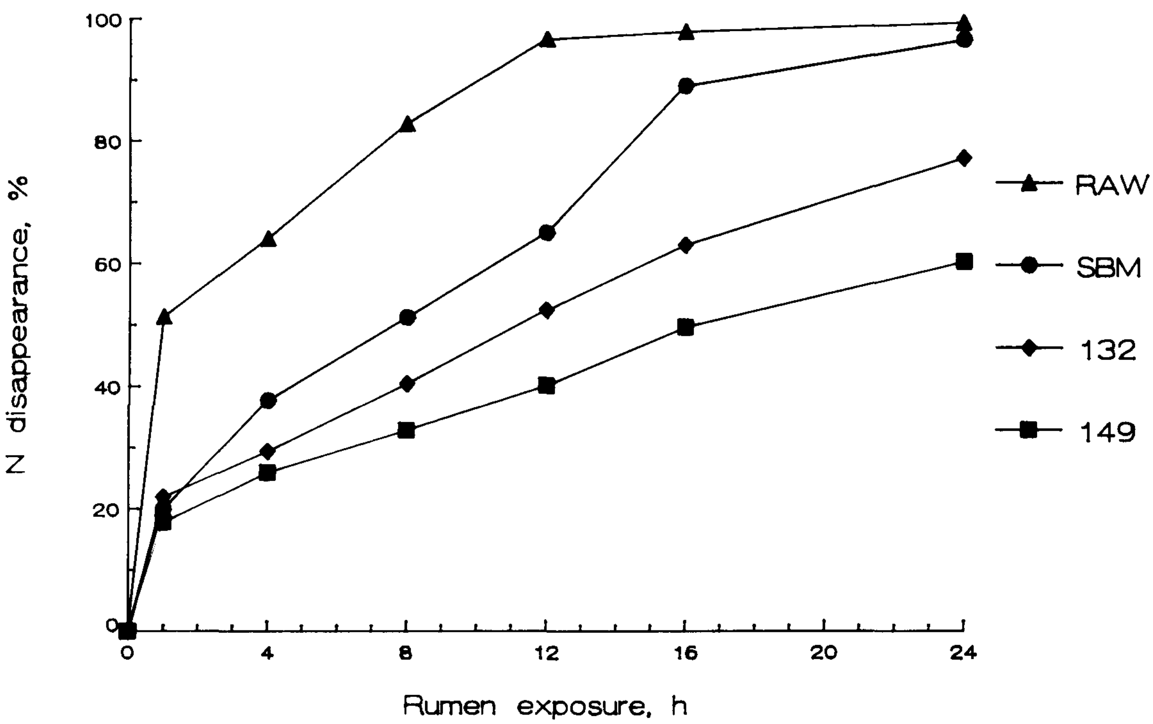

Figure 3. Nitrogen disappearance from dacron bags containing soybean meal (SBM), whole soybeans (RAW) or whole soybeans extruded at 132°C (132) or 149°C (149).

Using the same soybean sources, Stern et al. (1985) used ruminal and intestinal cannulated lactating Holstein cows to measure protein degradation in the rumen and amino acid flow and absorption in the small intestine (Table 1). Flow of total amino acids to the duodenum and subsequent absorption in the small intestine were lowest for the diet containing unprocessed whole soybeans. Extrusion of whole soybeans at 132 and 149°C increased flow of amino acids to the duodenum approximately 10% and caused a 17% higher absorption (g/day) in the small intestine compared with unprocessed soybeans. This effect was probably due to increased resistance of protein in extruded whole soybeans to microbial degradation. Amino acid absorption in the small intestine, expressed as percentage of amino acid flow to the duodenum, was higher for the extruded soybean diets, indicating that heat treatment did not overprotect the protein. Lower digestion in the intestine with unprocessed soybeans could possibly be attributed to higher trypsin inhibitor activity compared to the heat processed soybeans. Mielke and Schingoethe (1981) determined that trypsin inhibitor activities of extruded soybeans and raw soybeans were 2.7 and 24.0 trypsin inhibitor units/mg, respectively.

Table 1. Daily amino acid intake, flow and digestion in the digestive tract of cows fed diets containing soybean meal, whole soybeans and whole soybeans extruded at 132 and 149°C.

Amino acid	Soybean meal	Whole soybeans	Whole soybeans extruded at 132°C	Whole soybeans extruded at 149°C
Intake, g/day	2081	2064	2085	2097
Degradation in stomach, % of intake	71.7[a]	73.5[a]	58.7[b]	57.7[b]
Flow to duodenum, g/day	2265[a]	2090[b]	2314[a]	2316[a]
Bacterial	1679	1535	1456	1476
Dietary	586[a]	554[b]	857[a]	885[a]
Absorption in small intestine, g/day	1617[ab]	1459[b]	1749[a]	1777[a]
% entering	71.4[b]	69.8[b]	75.7[a]	75.4[a]

[a,b]Means in the same row not having a common superscript differ (P<.05).

FULL FAT SOYBEANS AS A LIPID SOURCE FOR RUMINANTS

The need to increase energy density of diets for high producing cows in early lactation has resulted in more fat supplementation. This is a feeding strategy that has become more common in recent years. Fat in the form of whole soybeans is relatively inexpensive and research along with field experience has shown that soybeans are a good source of energy (Linn, 1986). The high fat of soybeans is attractive during early lactation when the caloric (energy) density of the diet can be increased by replacing carbohydrate or corn energy with fat. However, because soybeans contain more than 80% unsaturated fatty acids, there is some concern about their effect on ruminal fermentation and milk fat depression.

Palmquist and Jenkins (1980) indicated that unsaturated fatty acids are more likely to adversely affect ruminal fermentation and fiber digestion than saturated fatty acids. Chalupa et al. (1984) explained that unsaturated fatty acids are likely to adhere to feed particles and therefore are more available to exert toxic effects on ruminal microorganisms. In addition, microbial biohydrogenation of polyunsaturated fatty acids within the rumen may result in formation and accumulation of trans-fatty acids, which have been implicated as a causative effect in inducing milk fat depression (Selner and Schultz, 1980).

Stern and Satter (1981) noted a large reduction in linoleic (C18:2) and linolenic (C18:3) acid content of full fat soybeans with increasing extrusion temperature. This was presumably due to oxidation of the polyunsaturated fatty acids. When feeding extruded soybeans, raw soybeans and soybean meal to dairy cows, stearic acid (C18:0) was the predominant fatty acid to reach the duodenum, resulting from biohydrogenation in the rumen (Table 2). Extrusion of whole soybeans resulted in higher oleic acid flow to the duodenum compared to raw soybeans. These changes need to be investigated further to determine the influence of heat processed soybeans on fatty acid composition of milk and potential effects on milk fat depression and body fat composition.

Table 2. Fatty acid flow to the duodenum of cows fed diets containing soybean meal, whole soybeans and whole soybeans extruded at 132 and 149°C.

	Soybean source			
			Whole soybeans extruded at	
Fatty acid	Soybean meal	Whole soybeans	132°C	149°C
Flow to duodenum,				
palmitic (C16:0)	56^{a}	78^{b}	82^{b}	76^{b}
stearic (C18:0)	190^{a}	330^{b}	379^{b}	347^{b}
oleic (C18:1)	50^{a}	84^{b}	123^{c}	119^{c}
linoleic (C18:2)	24^{a}	58^{b}	40^{ab}	38^{ab}

[a,b,c]Means in the same row not having a common superscript differ (P<.05).

The form in which soybean oil is fed to lactating cows can affect animal performance. The effects of adding unprotected soybean oil to diets of lactating cows has been investigated. Additions of about 10% soybean oil to the concentrates did not affect milk production, milk fat or milk protein percentages in one study (Banks et al., 1980a) but did increase milk production and tended to lower milk protein percentage in another (Banks et al., 1976). The frequency of feeding concentrates containing 5, 7 or 10% unprotected soybean oil was shown to affect milk fat percentage (Banks et al., 1980b). Twice a day feeding of concentrates depressed milk fat percentage, whereas continuous feeding (24 times/day) increased milk fat percentage. The feeding of unprotected soybean oil was found to depress milk fat percentage in cows, while an equivalent amount of oil fed as raw soybeans increased milk fat percentage (Banks et al., 1980b). Larson and Schultz (1970) observed the same effect and speculated that the slow release of oil from soybeans in the rumen allows for a more complete hydrogenation of fatty acids. In beef cattle, Putnam et al. (1969) showed that average daily gains decreased when diets contained 5% soybean oil. In contrast, when fat was supplemented in diets of calves as whole soybeans rather than as free oil, growth was similar to that of calves fed soybean meal (Daniels et al., 1973).

INFLUENCE OF FULL FAT SOYBEANS ON ANIMAL GROWTH

Dysli et al. (1967) observed a decrease in organic matter digestibility and average daily gain (ADG) in sheep that received raw soybeans compared with heated soybeans or soybean meal. When raw soybeans were fed to beef cattle as a protein supplement, ADG was similar to that of cattle receiving soybean meal

(McCormick et al., 1983). In contrast, Erickson and Barton (1987) found that lambs receiving soybean meal as the protein supplement had higher ADG (.27 kg/d) than lambs receiving whole soybeans (.23 kg/d).

Rule et al. (1986) determined the effects of dietary extruded sobyeans compared to soybean meal on growth of steers from 309 to 474 kg body weight and on sensory characteristics. No differences were observed for ADG, however extruded soybeans caused slightly fatter carcasses and larger ribeye areas. Overall sensory score was less for steaks from steers fed extruded soybeans. There were negative correlations between the sensory scores and proportions of linoleic acid (C18:2), the major fatty acid of soybean oil. This suggests that increasing the proportion of linoleic acid in lipids of beef decreases the palatability of the beef. Rule and Beitz (1986) also found that feeding steers extruded soybeans to raise the fat content of the diet to 6% increases the proportion of polyunsaturated fatty acids of tissue lipids of cattle. This altered composition results from an increased amount of these fatty acids being available for absorption by the small intestine.

To evaluate utilization of processed whole soybeans by calves, raw soybeans were compared to soybeans processed at 138 and 171°C in a nitrogen balance experiment (Abdelgadir et al., 1984). Nitrogen retention was similar when calves consumed either of the heat-treated soybean diets but less for the raw soybean diet. In a second experiment, they found that calves consuming starters containing soybeans processed at 171°C consumed more feed, gained faster and had less scours than calves consuming raw soybeans or soybean meal supplemented with animal fat.

In a recent study, Stern et al. (1987) fed starter diets consisting of ground corn and alfalfa supplemented with the following nitrogen supplements: urea (U), soybean meal (SBM), whole soybeans (RAW), whole soybeans extruded at 149°C (ES) and extruded whole soybeans plus urea (ES+U) to Holstein steer calves. Results from this study are presented in Table 3. Calves fed starter diets containing extruded soybeans plus urea gained at a faster rate to 181 kg

Table 3. Performance of growing Holstein steers fed various nitrogen supplements.

	Nitrogen supplement				
Item	U	SBM	RAW	ES	ES+U
Up to 181 kg,					
ADG, kg/d	1.04^{c}	1.12^{b}	1.01^{c}	1.11^{b}	1.18^{a}
Feed intake, kg/d	3.51^{a}	3.47^{a}	3.20^{b}	3.42^{ab}	3.61^{a}
Efficiency, feed/gain	3.37^{a}	3.09^{b}	3.17^{ab}	3.09^{b}	3.07^{b}
ADG from:					
181 to 476 kg	1.19^{a}	1.18^{a}	1.22^{a}	1.25^{a}	1.20^{a}
weaning to 476 kg	1.14^{bc}	1.17^{ab}	1.12^{c}	1.18^{a}	1.20^{a}
Days on feed from					
weaning to 476 kg	365.2^{a}	351.4^{ab}	366.8^{a}	347.2^{b}	342.0^{b}

^{a,b,c}Means in the same row not having a common superscript differ ($P<.05$).

than calves fed all other diets. Calves fed urea and raw soybeans had the lowest ADG while feed intake was lowest for calves fed raw soybeans. The advantage gained by calves fed extruded soybeans plus urea up to 181 kg was maintained throughout the experiment compared to the urea and raw soybean diets. It also took approximately three weeks less time for steers fed extruded soybeans to reach 476 kg compared to steers fed raw soybeans. These results indicate that it might be beneficial to feed readily fermentable nitrogen (urea) in conjunction with protected protein.

INFLUENCE OF FULL FAT SOYBEANS ON MILK PRODUCTION

Heat Processed Soybeans vs Raw Soybeans and Soybean Meal

Inclusion of full fat soybeans in diets fed to lactating cows has been primarily in the form of raw or heat processed (extruded) soybeans. The number of lactation experiments comparing raw and heat processed soybeans are limited and quite variable. Several studies (Block et al., 1981; Mielke and Schingoethe, 1981; van Dijk et al., 1983) showed no significant improvement in milk production when feeding extruded whole soybeans vs raw soybeans. In contrast, Owen and Edionwe (1986) reported a 1.4 kg increase in daily milk yield with roasted soybeans compared to raw soybeans. They also found that grinding of the soybeans seemed to have practically no effect on lactation whether raw or roasted, compared with feeding the soybeans whole or unground. Ruegsegger and Schultz (1985) observed some stimulation of milk production (about 1 kg/day) feeding heat treated whole soybeans to high producing cows in early lactation compared to soybean meal.

Most of the published research with heat processed soybeans and other protected protein sources has been with corn silage as the primary forage source. Because ruminal degradation of protein in alfalfa hay or silage is greater than with protein in corn silage, Voss et al. (1987) suggested that the response to protected proteins may be different with alfalfa silage. They found that feeding roasted whole soybeans increased milk yield 2.0 kg/day, 4% fat corrected milk 4.6 kg/day and milkfat .23 kg/day when compared to solvent extracted soybean meal with alfalfa silage as the forage source. No differences in milk production were found when diets contained equal amount of corn silage and alfalfa silage.

Milk Composition

Mielke and Schingoethe (1981) reported that protein percent in milk was lower for heat treated and raw soybeans compared to soybean meal, probably because of the higher fat content of those diets. Rations with larger amounts of lipids (5 to 12%) have been found to reduce milk protein (Mattos and Palmquist, 1974; Palmquist and Jenkins, 1980). Palmquist and Moser (1981) suggested that reduced milk protein concentrations in cows fed high fat diets may be due to an insulin resistance, which affects utilization of amino acids for milk protein synthesis. Reduced milk fat percentages have been reported (Block et al., 1981; van Dijk et al., 1983) when cows were fed extruded soybeans. Block et al. (1981) fed extremely high (6.62 kg) amounts of heated soybeans, well above recommended levels (2.27 kg). This may have elicited abnormal responses resulting in milk fat depression from 3.50 to 2.52%. In addition, calcium levels recommended (.6 to .7%) for most dairy cattle diets may not be adequate when feeding full fat soybeans. Because additional dietary fat reduces absorption of calcium, Palmquist and Jenkins (1980) recommended that diets which contained additional fat should contain .9 to 1.0% calcium to prevent milk fat depression.

Feeding Guidelines

Based on research and field experience, Linn (1986) adopted the following guidelines which apply to the feeding of both raw and heat processed soybeans to dairy cows.

1. Limit soybeans to 2.27 kg/cow/day or less. In most rations, 1.36 to 1.81 kg should be adequate. Do not exceed 20% soybeans in a grain mix.

2. Calcium content of rations should be between .8 and 1.0%, DM basis. This is to ensure that cows receive adequate calcium, as fats combine with calcium to form soaps which limits calcium availability.

3. Raw soybeans must not be mixed with urea because they contain urease, which breaks down urea to ammonia. Heat processed soybeans can probably be mixed with urea but it is not recommended.

4. Make sure that adequate amounts of forage and fiber are included in the ration. Feeding fat may reduce ruminal fiber digestibility and low milk fat percentages may occur if acid detergent fiber content of rations are not at 19% (DM basis) or higher.

5. Grind, roll or crack no more than about one week's feeding supply of soybeans to avoid rancidity problems, especially in warm weather.

CONCLUSIONS

Fat supplementation of ruminant diets, especially in high producing dairy cows, is a feeding strategy that is becoming more acceptable. Full fat soybeans are a relatively economical source of fat and also provide a good source of protein, which is unique among fat sources as most contain little or no protein. These factors make full fat soybeans a very attractive feedstuff for ruminants. However, feeding strategies using full fat soybeans need to be more clearly defined to best utilize the fat and protein within. Some strategies requiring clarification are:

1. Physical form of raw soybeans - whole, ground, rolled, cracked
2. Processing method - heat treatment (extrusion, roasting ,etc.)
3. Maximum level of feeding full fat soybeans
4. Forage source and level
5. Level of calcium supplementation
6. Stage of animal production for best response

The above information should increase competitiveness of full fat soybeans with other fat and protein sources fed to ruminants.

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