Soy Protein Alternatives for Lactating Dairy Cows

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Most soybeans are processed to remove the oil for use as edible fat. The defatted co-product, soybean meal, is the most widely used protein supplement in the feed industry. Dairy producers, particularly in soybean cropping areas, often use whole soybeans as a source of fat and protein in rations for lactating cows.

Relative to other protein supplements for lactating dairy cows, solvent-extracted soybean meal (SBM) has a favorable amino acid profile (Schwab, 1995) and high post-ruminal protein digestibility (Stern et al., 1994), but its ruminal protein degradability is high (Stern et al., 1994). In addition to its high ruminal degradability (Faldet et al., 1992), the protein in raw, whole soybeans suffers reduced intestinal digestibility because of trypsin inhibitor (Aldrich et al., 1997).

Various methods of heat processing are used commercially to reduce the degradation of soy protein by rumen microbes. This reduction in ruminal protein degradation via heat treatment occurs because of Maillard type reactions between sugar residues and amino acids (Van Soest, 1982). Roasting and extrusion are the two common commercial methods of heat treating whole soybeans. Commercial methods for producing heat-treated SBM include cooker-expeller processing of soybeans (SoyPlus® , West Central Cooperative, Ralston, IA; Soy Best, Grain States Soya Inc., West Point, NE), extruder-expeller processing of soybeans (Soy King, Topeka, KS; InstaSoy-XP, Soy-Co, Adams, WI; SoyMax, Reinemann&Sons, Reedsville, WI), non-enzymatic browning of dehulled, solvent-extracted soybean meal (Soy Pass® , Ligno Tech USA, Overland Park, KS), and cooker processing of dehulled, solvent-extracted soybean meal (Amino Plus® , AGP, Omaha, NE). The purpose of this paper is to review published research on the myriad of soy protein alternatives that are available to formulate lactating dairy cow rations for undegraded intake protein (UIP).

HEAT PROCESSED SOYBEANS

Soybeans contain 42% crude protein (CP) and 19%-20% fat (DM basis; NRC, 1989). The ruminal undegradability of the protein in raw soybeans is 26% (Faldet et al., 1992; NRC, 1989). Roasting and extrusion are commercially available methods of heat treatment for increasing the UIP content of soybeans.

Roasted Soybeans

Roasting of soybeans is commercially done either by passing the beans through a flame as they move rapidly through a rotating drum or by exposing the beans to dry heat with their transit time through the heating chamber controlled by a conveyor system. It has become more common to steep the beans after roasting to allow for a more thorough heat treatment.

<u>Lactation Performance</u>

Socha (1991) conducted a literature review of 26 feeding trials involving heat processed soy protein. Cows fed roasted soybeans produced more milk and fat-corrected milk (FCM) than cows fed raw soybeans (3.1 and 2.7 lb/cow/day, respectively) or unheated SBM (4.2 and 6.0 lb/cow/day, respectively). Many of these trials undoubtedly evaluated roasted soybeans that were not optimally heat-treated.

Faldet and Satter (1991) evaluated roasted soybeans that were steeped for .5 to 3 hours following roasting to a soybean temperature upon exiting the roaster of 295° F. Ruminal undegradabilities of the protein (inhibitor in vitro system of Broderick, 1987) in raw soybeans, unheated SBM, and roasted soybeans fed in this trial were 28%, 36%, and 67%, respectively. Cows fed roasted soybean diets produced about 10 lb/cow/day more milk than cows fed raw soybean or unheated SBM diets.

<u>Quality Evaluation</u>

An evaluation of 13 commercial samples of roasted soybeans revealed wide variation in the UIP content of these samples (Faldet and Satter, 1991). Ruminal undegradabilities of the protein (inhibitor in vitro system of Broderick, 1987) ranged from 36% to 58% and averaged 48%. Holding soybeans for at least 30 minutes postroasting without cooling increased ruminal undegradability of the protein to 66% on average with a range of 60% to 75% for the 8 samples tested. Satter et al. (1991) recommended that roasted soybeans should exit the roaster at 295° F and then be held for 30 minutes before cooling.

Hsu and Satter (1995) recommended use of protein dispersibility index and 420-nm absorbance for routine monitoring of the quality of commercially roasted soybeans. The PDI gives an indication of the thoroughness of heating for deactivating trypsin inhibitor and increasing the UIP content of soybeans. Measurement of absorbance at 420 nm gives an indication of possible heat damage of the protein through excessive heat exposure in the roasting process. Hsu and Satter (1995) concluded that the ideal range for PDI was 9% to 11%. A PDI between 11% and 14% indicates marginal heating and under-heated soybeans have a PDI greater than 14% (Satter et al., 1993). The PDI assay is available commercially through testing labs.

Particle Size

Although, grinding reduces fecal excretion of soybeans (Dhiman et al., 1997), it also increases the ruminal degradability of the protein in roasted soybeans (Tice et al., 1993). Dhiman et al. (1997) found that cows fed roasted soybeans rolled to half and quarter sizes produced 2.9 or 3.8 lb/cow/day more milk than cows fed roasted soybeans rolled to quarter and smaller sizes or ground, respectively. They concluded that properly roasted soybeans should contain mostly half and quarter pieces.

Extruded Soybeans

Extruded soybeans pass through a machine with a spiral, tapered screw that forces them through a tapered head. In the process the soybeans are ground into a meal and heated through heat generated via friction. This process also ruptures oil vesicles releasing free oil from the soybean; this is the primary difference between unground roasted soybeans and extruded soybeans. Extrusion equipment has been available from Insta-Pro, a Division of Triple F Feed Company, Des Moines, IA. Their HTP extruded soybean product contains 7.5% of a mixture of sodium bentonite and lignin sulfonate; this mixture typically exits the extruder at 270 to 300° F (Satter et al., 1991).

The literature review of Socha (1991) revealed that cows fed extruded soybeans produced 3.5 lb/cow/day more milk than cows fed unheated SBM, but only 2.2 lb/cow/day more FCM because of a .10 percentage unit reduction in milk fat test. Further, cows fed extruded soybeans produced 2.0 lb/cow/day more milk than cows fed raw soybeans, but there was no difference in FCM because of a .23 percentage unit reduction in milk fat test.

Socha (1991) evaluated extruded soybeans relative to unheated SBM, roasted soybeans, and raw soybeans in multiparous Holstein cows in early lactation. Ruminal undegradabilities of the protein (inhibitor in vitro system of Broderick, 1987) in the unheated SBM, roasted soybeans, extruded soybeans, and raw soybeans were 32%, 56%, 56%, and 24%, respectively. Cows fed extruded soybeans produced 6.6 lb/cow/day more milk than cows fed unheated SBM or raw soybeans and 5.3 lb/cow/day more FCM than cows fed raw soybeans. Milk fat test was .20 and .23 percentage units lower for cows fed extruded soybeans than cows fed raw soybeans and unheated SBM, respectively. Milk fat test depression is a limitation to the feeding of high levels of extruded soybeans. This is likely related to the free soy oil in extruded soybeans (Mohamed et al., 1988).

HEAT PROCESSED SBM

Cooker-Expeller Processed SBM

The company nutrient profile sheet for SoyPlus® lists 48.9% CP, 5.7% fat, 8.0% ADF, and 23.7% NDF (DM basis). Their listed estimate of ruminal undegradability of the protein (inhibitor in vitro system of Broderick, 1987) is 60%. Literature estimates of the ruminal undegradability of the protein (inhibitor in vitro system of Broderick, 1987) in SoyPlus® were 64% (Broderick, 1986), 67% and 59% (Broderick et al., 1990), 56% (Broderick, 1987), 55% (Hoffman et al., 1991), and 56% (Luchini et al., 1996) with comparable estimates for unheated SBM of 39%, 30% and 37%, 28%, 40%, and 33%, respectively. In vitro evaluation of intestinal digestion of ruminal escape protein for expeller processed SBM showed protein digestibility above 90% (Stern et al., 1994).

Broderick (1986) reported comparable utilization of a SoyPlus® diet containing only 60% as much supplemental protein as the unheated SBM diet. In Broderick et al. (1990), cows fed SoyPlus® diets containing 60% as much supplemental protein as the unheated SBM diets had higher milk yield in one trial and similar milk yields in two other trials. Hoffman et al. (1991) did not observe a milk production response to increasing dietary UIP by replacing unheated SBM with SoyPlus® . Dado et al. (1990) reported higher milk production for SoyPlus® over unheated SBM in cows fed 26% but not 32% NDF diets.

The company nutrient profile sheets for Soy Best list 47.7-48.3% CP, 5.0-5.1% fat, 8.0% ADF, and 27.3% NDF (DM basis). Their listed estimate of ruminal undegradability of the protein (in vitro ammonia release assay of Britton et al., 1978) is 56-58%. A literature estimate of the ruminal undegradability of the protein (inhibitor in vitro system of Broderick, 1987) in Soy Best was 52% (Titgemeyer and Shirley, 1997).

Titgemeyer and Shirley (1997) observed a 2.6 lb/cow/day increase in FCM for cows fed Soy Best versus unheated SBM in 18.5% CP diets. Shirley et al. (1997) reported greater FCM production for early lactation cows fed a Soy Best diet (16% CP-40% UIP) versus cows fed unheated SBM or animal protein diets (16% and 18% CP-35% UIP or 16% CP-40% UIP, respectively).

Extruder-Expeller Processed SBM

There are several extruder-expeller processed SBM products available commercially. No controlled research data were found on these products. Company testing for the ruminal undegradability of the protein in these products is extremely limited. Company nutrient profile sheets generally indicate a higher fat content than reported for cooker-expeller products (8.0-8.5% vs. 5.0-5.7% of DM).

Non-Enzymatically Browned SBM

Cleale at al. (1987a, 1987b) demonstrated ruminal protection of SBM protein heated at 300° F for 30 minutes after mixing with xylose and adjusting the moisture content of the mixture to 17%. Non-enzymatic browning of dehulled, solvent-extracted soybean meal is employed commercially by Ligno Tech USA to produce Soy Pass® .

Nakamura et al. (1992) evaluated non-enzymatically browned SBM in early lactation dairy cows. Treated SBM was heated for two hours at 200° F after mixing with 5% sulfite liquor containing 20% xylose and adjusting the moisture content of the mixture to

17%. Ruminal undegradability (12-hour in situ incubation) of the treated SBM protein was 79%. Unheated SBM was the source of supplemental protein in a 16% CP control diet. Non-enzymatically browned SBM diets contained 50% as much supplemental protein from SBM as the unheated SBM diet either with or without urea in 13% and 16% CP diets, respectively. There were no differences in lactation performance across the three treatments. These authors concluded that non-enzymatically browned SBM supports the same milk production at half the amount of unheated SBM. Annexstad et al. (1990) reported higher milk production for multiparous cows in early lactation fed 18% CP diets containing supplemental protein from non-enzymatically browned SBM versus unheated SBM.

Literature estimates of the ruminal undegradability of the protein in non-enzymatically browned SBM were 66% (Stern et al., 1994; in situ), 69% and 82% (Luchini et al., 1996; in situ and Broderick inhibitor in vitro system, respectively), and 79% (Nakamura et al., 1992; in situ). Non-enzymatic browning of SBM did not compromise protein digestibility in duodenally-cannulated steers (Cleale at al., 1987b). In vitro evaluation of intestinal digestion of ruminal escape protein for non-enzymatically browned SBM showed protein digestibility at 88% (range 82-92% on 6 samples) which was similar to unheated SBM (Stern et al., 1994). The company nutrient profile sheet for Soy Pass® lists 53.2% CP, 1.0% fat, 5.8% ADF, and 7.7% NDF (DM basis). Their listed estimate of ruminal undegradability of the protein is 74%

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