PENNSTATE

College of Agricultural Sciences • Cooperative Extension

Soybeans and soybean byproducts for dairy cattle

Virginia Ishler and Gabriella Varga

DAIRY& ANIMAL SCIENCE

Department of Dairy and Animal Science
The Pennsylvania State University
324 Henning Building
University Park, PA 16802
(814) 865-5491 • FAX (814) 865-7442
www.das.psu.edu/teamdairy/

Topics Include:

INTRODUCTION

Incorporating soybeans and its byproducts in the rations for dairy cattle is a fairly common practice. They are an excellent source of essential amino acids and they fit into any type of forage-based ration. Depending on how they have been processed, they can provide high quality protein, degradable, undegradable and soluble protein, energy, fat, and fiber (Table 1).

Soybeans provide protein and energy to the ration. If soybeans have been properly heat-treated then they can provide additional rumen undegradable protein (RUP) and fat. Soybeans that have not been heated provide a source of degradable and soluble protein.

Soybean oil meal is used as a protein source for dairy cattle. There are some heat-treated soybean meal products that provide additional RUP to the diet.

Soybean hulls provide an excellent source of digestible fiber. They are often incorporated into dairy cattle diets to help stretch forage supplies or to minimize risk from rumen acidosis.

There is no question that soybeans and its byproducts can provide various nutrients to the rations of dairy cattle. However as with any feed, there are some limitations that need to be recognized so their full benefits to the dairy cow can be achieved.

RAW SOYBEANS

Soybeans that have *not* been heat-treated can be incorporated successfully into dairy cattle rations. They provide a source of degradable and soluble protein as well as energy in the form of fat. The suggested feeding level is 10 percent of the total ration dry matter. For lactating cows the suggested feeding level would probably be no more than 4 to 5 pounds as-fed.

Raw soybeans do contain enzymes that may result in some deterioration in the fat portion of the beans. These enzymes include lipase and lipoxidase. Lipase may result in the hydrolytic rancidity or liberation of free fatty acids from the oil present in the soybeans. They can be inactivated at temperatures greater than 175^{o}F. Lipoxidase promotes oxidative rancidity or peroxide formation. Peroxides may be toxic to the rumen microbes at high levels of intake. Young calves appear to be especially susceptible to peroxide toxicity and therefore raw soybeans should be avoided in rations for calves less than 4 months of age. Lipoxidases are destroyed at temperatures exceeding 120^{o}F.

To avoid problems associated with lipase and lipoxidase, i.e. rancidity, it is recommended to store raw soybeans whole. If they are not going to be fed whole, they should be rolled, crushed, or ground prior to inclusion in a grain mix. Ideally the grain mixture should be prepared every 2 weeks in winter and weekly during summer.

Raw soybeans also contain the enzyme urease, which hydrolyzes ammonia from urea. For this reason it is generally not recommended to include urea in a complete feed containing raw beans. Urea that is in contact with raw cracked or raw ground soybeans can release ammonia in a relatively short period of time. Cows are fairly sensitive to gaseous ammonia so when too much nitrogen is present in the ration as ammonia, a drop in dry matter intake can occur.

RAW SOYBEANS, CONT.

In a total mixed ration system, if whole raw soybeans were used rather than raw cracked or raw ground beans, it is doubtful that urea would be exposed to appreciable urease activity. However, that's provided few beans were broken during handling and mixing. Ensiling material made with urea as an additive can be used with raw beans since little or no urea remains as such after normal ensiling.

Raw soybeans do contain a trypsin inhibitor and possibly other antienzymes, which may reduce protein digestion and utilization by single-stomached animals. Soyin, a protein, also is present in raw beans. This is toxic to some single-stomached animals. These factors in raw beans, however, do not appreciably affect cattle, because of their unique rumen metabolism.

HEAT-TREATED SOYBEANS

Heat-treated soybeans, on a dry matter basis, can range between 33 to 44% crude protein, 15 to 22% fat, and generally have a moisture content of 12%. An average RUP value as a percent of crude protein for properly heated soybeans is 50%.

The two most common methods of heat treatment are roasting and extrusion. They both have their advantages and disadvantages.

ROASTED SOYBEANS

Roasted soybeans are a very popular way of feeding soybeans, supplying both RUP and fat. They work well in most forage type rations with the greatest benefits being observed in heavy haycrop silage diets. They can be included in the ration up to 18% of the total ration dry matter. However, in many situations, when used with other concentrate ingredients, RUP and/or fat will limit the amount of beans that can be fed.

There are two main types of roasters used in the field – a drum roaster and high temperature air dryers where soybeans are conveyed over a perforated floor through which hot air is blown. With drum roasters soybeans are dropped into a rotating drum where air temperatures may range from 400^{o}F to 600^{o}F. Soybeans will remain about one minute in the hot air environment before exiting. If beans remain in the roaster longer than one minute, they can get scorched. The amount of damage to scorched beans typically is minimal.

Equipment that conveys soybeans across a perforated floor through which hot air is blown causes less scorching and may be more energy efficient than the drum roaster. This type of equipment usually is more expensive.

The main objective in the roasting process is to achieve even heating and allowing the beans to be steeped or held without cooling for additional time. Soybeans passed through a drum roaster can produce a fairly consistent product. The most commonly used method is open-flame roasting. This is where more variation occurs in respect to RUP levels.

Factors affecting RUP levels when using open-flame roasters are moisture content of the beans, how clean the beans are, and the environmental temperature. It is not unusual to see RUP range from 40 to 65% of the crude protein. This may explain some of the variable results observed in milk production response in both controlled research and field trials.

HEAT-TREATED SOYBEANS, CONT.

Researchers at Wisconsin have demonstrated the differences that occur in RUP and lysine availability when various heat-treatments are used (Table 2). It appears that optimum heat treatment for soybeans intended for lactating dairy cattle is to heat soybeans to 295°F and then steep them without cooling for an additional 30 minutes. The steeping temperature will always be less than the temperature of the soybeans exiting the roaster because the soybeans will be losing moisture by evaporation. This will cause the temperature of steeped beans to be 10 to 20 degrees cooler, depending on the moisture content of the beans.

Measuring for proper heat treatment

Some of the variation in animal production responses when roasted soybeans have been fed may be from improper roasting procedures. If soybeans are roasted with too little heat, then the amount of RUP supplied in the ration may be greatly reduced. When too much heat is used Maillard products can be produced, which makes the protein unavailable in the small intestine. The amount of lysine available post-ruminally can also be diminished due to improper roasting procedures. For these reasons it is necessary to implement some quality control measures so dairy producers know that they are purchasing a high quality product.

There are tests available to determine if the heat treatment has been adequate and not excessive. A common method is the urease activity test. It is expressed as increased unit of pH. Beans with values of 0.05 to 0.30 are considered reasonable evidence of proper cooking. If used in a TMR or a high moisture grain mix containing urea, a range of 0.05 to 0.10 is preferred.

Another popular test is the protein dispersibility index (PDI) test. The solubility of a feed ingredient decreases as heat exposure time and temperature increases. Use of this procedure can determine how much heat the soybeans have been exposed to during roasting.

The ideal PDI value for optimally heated soybeans is a value of 9 to 11. Soybeans with a PDI value greater than 14 should be considered under heated. A major disadvantage of the PDI system is that it loses sensitivity as the optimum heat treatment is approached. For example, as the PDI goes from 14 to 9, there may be an increase in RUP and post ruminal available lysine (Table 2). Even a small change could affect the value of heated soybeans. The lack of sensitivity in this range is a weakness of the PDI procedure.

Particle size of roasted soybeans

Most research indicates that there is an influence of particle size on the protein degradability characteristics of roasted soybeans. Particle size of roasted soybeans can affect how the high producing dairy cow utilizes the protein. The concern is that the protein in small particles is likely to degrade more rapidly in the rumen than the protein in large particles.

Researchers from the University of Wisconsin looked at the response of lactating dairy cows to increasing levels of whole roasted soybeans. Cows were fed a ration containing 50:50 forage to concen-trate ratio with 0, 12, 18, and 24 percent of the diet dry matter as whole roasted soybeans. Production and milk composition are listed in Table 3. The researchers found that milk production was improved by supplementing the roasted beans at 12 to 18 percent of the diet dry matter.

HEAT-TREATED SOYBEANS, CONT.

In another study from Wisconsin, milk production response was evaluated for dairy cattle fed various particle sizes of roasted beans (Table 4). Cows were fed a diet consisting of alfalfa haylage, corn silage, high moisture ear corn, soybeans, minerals, and vitamins. Soybeans made up 18% of the ration (percent dry matter basis) in all treatments. The PDI value for the roasted soybeans was 10.6. The best production response was seen in whole/half and half/quarter particle sizes.

In a study conducted at Penn State, researchers investigated the effects of processing method on degradation characteristics of protein in situ. Two ruminally cannulated Holstein cows in early lactation were used to determine the effects of particle size on ruminal degradabilities of soybeans. The protein sources were raw and roasted soybeans that were either cracked or ground. Table 5 lists the effective ruminal degradabilities for the different soybean sources. The grinding of roasted soybeans increased the total surface area and allowed degradation of the substrate by the rumen microbes. The result was crude protein degradabilities for ground-roasted soybeans similar to cracked raw soybeans and ground soybean meal.

Based on several good studies it has been concluded that feeding roasted soybeans as whole/half and half/quarter is the optimum particle size to retain the RUP value of the feed. In TMRs the whole/half particle size should result in little or no separation, however, in grain mixtures or supplements, a half/quarter particle size may work better. If the goal of feeding roasted soybeans is to supply RUP, then grinding and pelleting is not recommended.

EXTRUDED SOYBEANS

Extruded soybeans are exposed to high temperatures, with the exit temperature of the beans ranging between 270^{o}F to 300^{o}F. Extrusion has a consistent, uniform type of heating. In the process, soybeans are ground, heated, pressed through a screw, producing a ribbon like product. Heat penetration is facilitated by physically shattering the seed. Because this process ruptures the fat vesicles within the soybean, there can be a rapid release of the oil in the rumen when fed to dairy cattle. Feeding extruded soybeans can result in milk fat depression.

Table 6 contains a summary of published and unpublished studies where roasted and extruded soybeans were compared to soybean meal and unheated soybeans in dairy diets. The average milk production response is an increase of 3 to 3.5 pounds of milk daily. This may be an underestimate because under heated soybeans were used in many of the comparisons.

SOYBEAN MEAL

Soybean meal is palatable, nutrient dense, high in digestibility, and a relatively consistent source of protein. It has an excellent amino acid profile. It is a concentrated source of protein and energy and is lower in fiber than most other oilseed meals.

There are two main types of soybean meal. One is solvent extracted soybean meal, which contains 44% crude protein. The other is dehulled, solvent extracted soybean meal, which contains 48% crude protein.

There are also high RUP soybean meal products, which have been heat-treated and supply RUP in dairy cattle rations. The incorporation of soybean meal type products should be evaluated based on what they supply to the ration and their price per unit of nutrient provided.

SOLVENT-EXTRACTED SOYBEAN MEAL

This product contains either 44% or 48% crude protein on an as-fed basis (50% and 54.5% on a dry matter basis, respectively). The 48% meal contains about 8% neutral detergent fiber (NDF) where the 44% meal is adjusted to 14% NDF by blending it with toasted ground soybean hulls.

Soybean meal is made by grinding soybeans, removing the fat with an organic solvent such as hexane, resulting in a low-fat soy product. This is the most common product on the market and utilized by the feed industry.

EXPELLER-EXTRACTED SOYBEAN MEAL

Soybean meal is produced by mechanically squeezing out the oil. Less oil is removed in this process and cows may find it more palatable because of less dustiness and fines. Because this product contains more oil compared to solvent-extracted, the energy value is slightly higher. Product availability is usually limited.

HIGH RUP SOYBEAN MEAL

The inclusion of regular soybean meal in a ration usually supplies a source of degradable protein. Only a small amount of soybean meal protein escapes the rumen. Heating or processing soybean meal initiates chemical reactions between sugars and amino acids, which increases its RUP value. Depending on the process used to treat soybean meal, RUP can range from 50 to 70%.

There has not been as many lactation studies conducted using heat-treated soybean meal as with heated soybeans. Minimal information is available regarding optimum heating conditions for soybean meal.

Commercial methods for producing high RUP soybean meal include cooker-expeller processed, extruder-expeller processed, and non-enzymatically browned. Making decisions on which product works best should be based on a review of controlled research data. Also, consider the impact the level of RUP will have on the feed and economic value of the soybean meal product.

Cooker-expeller processed

Commercial names that utilize this process are SoyPlus® and Soy Best®. The company nutrient profile for SoyPlus® on a dry matter basis is as follows:

Crude protein	48.9%
RUP	60.0%
Acid detergent fiber	8.0%
Neutral detergent fiber	23.7%
Crude fat	5.7%

There have been numerous studies conducted comparing SoyPlus® and unheated soybean meal. The research literature estimates the RUP range between 55 to 67%. Most of the research studies using SoyPlus® have shown a positive milk production response however, there have been a few studies where no difference was observed.

The company nutrient profile for Soy Best® on a dry matter basis is as follows:

Crude protein	47.7-48.3%
RUP	56.0-58.0%
Acid detergent fiber	8.0%
Neutral detergent fiber	27.3%
Crude fat	5.0-5.1%

SOYBEAN MEAL, CONT.

There have been several studies conducted comparing Soy Best ® and unheated soybean meal. The literature estimate of the RUP is 52%. Research studies using Soy Best ® usually show a positive milk production response.

Extruder-expeller processed

There are several extruder-expeller processed soybean meal products available, i.e. Soy King®, InstaSoy-XP®, SoyMax®. Controlled research data to determine RUP and milk production response when these products are fed have not been reported. Company testing for RUP is limited.

Non-enzymatically browned

Another name for this process is ligno-sulfate treated soybean meal. It was demonstrated that ruminal protection of soybean meal occurred when 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 is commercially available as Soy Pass®.

There have been numerous studies conducted comparing Soy Pass® and unheated soybean meal. The research literature estimates the RUP range from 66% to 82%. Most of the research studies using Soy Pass® show a positive milk production response; however, there have been a few studies where no significant differences were observed. In one study, the authors concluded that non-enzymatically browned soybean meal supports the same milk production at half the amount of unheated soybean meal.

The company nutrient profile for Soy Pass ® on a dry matter basis is as follows:

Crude protein	53.2%
RUP	74.0%
Acid detergent fiber	5.8%
Neutral detergent fiber	7.7%
Crude fat	1.0%

SOYHULLS

Soybean hulls are a byproduct of soybean processing. They are low in lignin, relatively high in energy, a good source of rumen digestible fiber, and low in nonstructural carbohydrates. Under most feeding situations, soyhulls can be included in dairy cattle diets up to 10% of the total ration dry matter. They can be incorporated into both lactating and dry cow diets.

Researchers from Nebraska evaluated soyhulls as a replacement for forage fiber in diets for early and mid lactation cows. The objective of the study was to determine the effect of adding coarsely chopped hay in diets where soyhulls replaced 25% or 42% of the forage dry matter (Table 7). The control ration consisted of 60% silage and no soyhulls.

Cows fed the high soyhull diet with hay yielded more milk and maintained a yield of 4% fat corrected milk similar to the control ration. The rations with high and low soyhull levels without added hay reduced milk fat yield and increased milk protein yield (Table 8). In this particular study, soyhulls successfully replaced some of the dietary forage, but only when in combination with coarsely chopped hay.

SOYHULLS, CONT.

Based on several research studies, it has been suggested that production and composition of milk may or may not be affected by the substitution of soyhulls for concentrate or forage. Inserting soyhulls in for too much forage may adversely affect rumen fermentation and reduce milk fat production and animal health. The other scenario of replacing too much cereal grains with soyhulls may decrease milk production because of lower energy intake. More research is needed to address the limitations of replacing forage and/or concentrate with soyhulls.

Issued in furtherance of Cooperative Extension Work, Acts of Congress May 8 and June 30, 1914, in cooperation with the U. S. Department of Agriculture and the Pennsylvania Legislature. T. R. Alter, Director of Cooperative Extension, The Pennsylvania State University.

TABLES

Table 1. Nutritional value of soy products used in dairy cattle diets (all values on a dry matter basis).[1, 2]

	Soybean hulls	Soybean meal 44%	Soybean meal 48%	Soybean meal, treated/high RUP	Soybean meal, expeller	Soybeans, heated	Soybeans, raw
DM %	90.0	88.0	88.0	92.0	91.0	90.0	86.0
CP %	12.1	50.0	54.5	48.7	48.5	40.9	40.9
RUP % of CP	30.0	35.0	35.0	51.0	60.0	50.0	26.0
RUP % of DM	3.6	17.5	19.1	24.8	29.1	20.5	10.6
Sol P % of CP	20.0	20.0	20.0	10.1	19.0	17.0	40.0
Sol P % of DM	2.4	10.0	10.9	4.9	9.2	6.9	16.4
ADF %	50.0	10.0	6.0	8.2	8.5	11.0	10.0
NDF %	67.0	14.0	8.0	20.6	12.5	13.8	13.0
TDN %	77.0	84.0	87.0	85.0	85.0	94.0	91.0
NEL, Mcal/lb	0.80	0.88	0.91	0.89	0.89	0.99	0.96
NFC %	13.5	27.3	30.0	18.1	27.1	21.9	23.3
Fat %	2.3	1.4	1.0	6.8	5.4	18.3	17.7
Ash %	5.1	7.3	6.5	5.8	6.5	5.1	5.1
Ca %	0.59	0.30	0.29	0.54	0.29	0.28	0.28
P %	0.21	0.68	0.70	0.73	0.65	0.65	0.65
Mg %	0.27	0.30	0.32	0.30	0.28	0.26	0.26
K %	1.34	2.12	2.28	2.34	1.90	1.89	1.89
S %	0.11	0.37	0.48	0.40	0.37	0.38	0.38
Mn, ppm	14.0	31.0	41.0	37.0	32.0	33.0	33.0
Cu, ppm	11.0	24.0	22.0	18.0	20.0	14.0	14.0
Zn, ppm	48.0	57.0	61.0	61.0	60.0	50.0	50.0
Fe, ppm	496.0	223.0	227.0	208.0	155.0	158.0	158.0
Se, ppm	0.10	0.11	0.11	0.11	0.11	0.10	0.10

Source: Dairy Reference Manual, third edition. NRAES-63.

[1] The expectancies in this table are for use when analyses are unavailable.

[2] DM=dry matter; CP=crude protein, RUP=rumen undegradable protein; Sol P=soluble protein; ADF=acid detergent fiber; NDF=neutral detergent fiber; TDN=total digestible nutrients; NEL=net energy of lactation; NFC=nonfiber carbohydrate; Ca=calcium; P=phosphorus; Mg=magnesium; K=potassium; S=sulfur; Mn=manganese; Cu=copper; Zn=zinc; Fe=iron.

TABLES

Table 2. Undegradable protein estimated by an in vitro method, lysine, available lysine and postruminal available lysine, and protein dispersibility index of nine soybean treatments.

Soybean Treatment	Undegraded Protein[1]	Lysine	Available Lysine	Postruminal Available Lysine[2]	PDI
	% of total CP	----------(mg/gN)----------			% of total CP
Unheated	33[a]	305	280	92[a]	86.3[a]
253°F-30 min	44[bc]	302	287	126[bc]	30.9[b]
275°F-0 min	46[cd]	313	295	136[bcd]	18.5[c]
275°F-30 min	55[de]	306	288	158[de]	14.3[d]
295°F-0 min	57[ef]	301	277	158[de]	10.8[e]
295°F-15 min	63[efg]	288	262	165[de]	9.6[e]
295°F-30 min	61[efg]	312	286	174[e]	9.5[e]
307°F-30 min	65[fg]	273	239	155[de]	9.4[e]
320°F-30 min	66[g]	255	218	144[cd]	8.6[e]
SE	2.9	21.1	19.1	9.6	.78

Source: Cornell Nutrition Conference Proceedings, 1994. Use of heat processed soybeans in dairy rations. L.D. Satter, T.R. Dhiman and J.T. Hsu.

[1] Each value is the mean of six determinations.

[2] Obtained by multiplying the fraction of undegraded protein by the amount of available lysine.

[a,b,c,d,e,f,g,h] Numbers with different superscripts in the same column differ ($p<.05$).

Table 3. Production and milk composition from cows fed different levels of whole roasted soybeans.

	Whole roasted soybeans, % dry matter basis			
	0	12	18	24
Milk, pounds/day	76.7[c]	82.5[b]	85.4[a]	85.4[a]
Milk fat, pounds/day	2.46[c]	2.62[a]	2.55[b]	2.57[b]
Milk protein, pounds/day	2.37[c]	2.49[b]	2.55[a]	2.57[a]

Source: Knapp D. M. et al., 1991. J. Dairy Sci. 74:2563-2572.

[a,b,c] Means in the same row with different superscripts differ ($p<.05$).

Note: diets contained 26-27% neutral detergent fiber, 16.8-19.7% crude protein, 0.76-0.79 NEL Mcal/pound., and fat levels for diets 0, 12, 18, and 24 were 3.0%, 5.1%, 6.4%, and 7.0% respectively (dry matter basis).

TABLES

Table 4. Dry matter intake and milk production of cows fed soybeans of different particle sizes.

	Treatment[1]						
	RWSB	RSBWH	RSBHQ	RSBQQ	RSBCG	SE	*P*
Dry matter intake, pounds/day	53.5	52.8	52.1	51.9	52.6	0.50	0.9
Milk, pounds/day	79.6[b]	83.8[ab]	85.1[a]	82.3[bc]	81.4[bc]	0.09	0.003
3.5% fat corrected milk, pounds/day	77.9[bc]	82.9[a]	81.8[ab]	77.2[c]	77.9[bc]	0.70	0.04
Milk fat, %	3.37	3.43	3.27	3.16	3.25	0.08	0.20
Milk protein, %	3.04	3.04	3.02	3.04	3.08	0.02	0.60

Source: Dhiman T. R. et al., 1996. J Dairy Sci. 80:1722-1727.

[1] RWSB=raw whole soybeans; RSBWH=roasted soybeans in whole and half sizes; RSBHQ=roasted soybeans in half and quarter sizes; RSBQQ=roasted soybeans in quarter and smaller sizes; RSBCG=coarsely ground roasted soybeans. The soybeans were heated at 295°F in a commercial roaster and steeped 30 minutes before cooling.

[a,b,c] Means in the same row with different superscripts differ as indicated.

Table 5. Effective ruminal degradability (%) of different soybean sources[1].

	Raw SB-C	Raw SB-G	Roasted SB-C	Roasted SB-G
Dry matter	53.2[b]	67.6[a]	53.3[b]	62.5[a]
Crude protein	47.7[bc]	63.4[a]	38.8[c]	51.9[b]

Source: Lykos T. et al., 1995. J. Dairy Sci. 78:1789-1801.

[1] SB-C=soybeans cracked and SB-G=soybeans ground.

[a,b,c] Means in the same row with different superscripts differ ($p<.05$)

TABLES

Table 6. Summary of animal response to feeding heated soybeans.[1]

Treatment	Milk	Change in Milk fat	Change in Milk Protein	Dry matter Intake
	pounds/day	%	%	pounds/day
Roasted soybeans	3.5(16)[2]	+0.06 (16)	-0.07 (16)	- 0.2 (16)
Extruded soybeans	2.9 (20)	-0.17 (19)	-0.06 (17)	+ 0.2 (18)

Source: Cornell Nutrition Conference Proceedings, 1994. Use of heat processed soybeans in dairy rations. L.D. Satter, T.R. Dhiman and J.T. Hsu.

[1] Soybean meal or unheated soybeans served as the control.

[2] Number in parenthesis is the number of comparisons.

Table 7. Nutrient composition of diets where soyhulls replaced some of the forage dry matter.[1]

Ingredients[2]	Control	LSH-	LSH+	HSH-	HSH+
			(% of dry matter)		
Alfalfa haylage	30.0	22.5	12.6	17.4	7.5
Corn silage	30.0	22.5	12.6	17.4	7.5
Alfalfa hay	-	-	19.8	-	20.1
Soyhulls	-	15.0	14.8	25.3	25.0
Shelled corn	16.9	17.2	18.9	15.1	17.0
44% soybean meal/ distillers grain	17.8	18.6	17.1	20.6	18.6
Chemical composition					
			(% dry matter basis)		
Dry matter	61.9	66.8	76.3	72.9	82.6
Crude protein	16.0	16.5	15.5	16.7	16.8
Neutral detergent fiber	29.5	31.7	32.2	33.3	34.2

Source: Weidner S.J. et. al. 1994. J. Dairy Sci. 77:513-521.

[1]LSH=low amount of soyhull replacing forage with (+) or without (-) hay. HSH= high amount of soyhull replacing forage with (+) or without (-) hay.

[2]All diets contained 4.2% to 4.3% mineral and vitamin supplement.

TABLES

Table 8. Performance of cows fed experimental diets where soyhulls replaced some of the forage dry matter.[1]

	Control	LSH-	LSH+	HSH-	HSH+	SE
Dry matter intake, pounds/day	50.9[b]	49.5[b]	49.1[b]	51.0[b]	56.8[a]	0.53
Milk production, pounds/day	70.2[b]	69.3[b]	66.0[c]	69.9[b]	76.3[a]	<0.1
4% fat corrected milk, pounds/day	66.0[a]	61.6[b]	53.9[c]	60.7[b]	69.5[a]	0.8
Fat, %	3.56[a]	3.26[b]	2.94[c]	3.20[bc]	3.36[b]	0.09
Protein, %	3.15[a]	3.14[a]	3.15[a]	2.93[b]	3.15[a]	0.07

Source: Weidner S.J. et. al. 1994. J. Dairy Sci. 77:513-521.

[1]LSH=low amount of soyhull replacing forage with (+) or without (-) hay. HSH= high amount of soyhull replacing forage with (+) or without (-) hay.

[a,b,c]Means within a row with no common superscripts differ (P<.05).