# EFFECTS OF SOYBEAN HULLS AS ENERGY AND PROTEIN SOURCES IN DAIRY COW DIET ON PERFORMANCE OF LACTATING DAIRY COWS

**Pipat Lounglawan***, **Wisitiporn Suksombat and Nattanit Puanpan**

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## Abstract

**The effects of feeding soybean hulls as energy and protein sources in concentrate on the performance of lactating dairy cows were studied. Twenty four Holstein Friesian crossbred (>87.5% Holstein Friesian) lactating dairy cows, averaging 16.3 ± 1.4 kg/d of milk, 84 ± 15 days in milk, 42 ± 5 mo old, and 415 ± 20 kg body weight, were blocked by milking days first and then by milk yield, body weight, and age into 2 groups of 12 cows. Cows within each group were further randomly assigned to 3 treatments of 8 cows each. The treatments were control (0% soybean hull; (SH)), 10% SH and 20% SH in the concentrates. Performance parameters showed that DM intake, CP intake, $NE_{LP}$ intake, milk yield, milk composition, and body weight change were similar in all treatments. However, milk fat and milk protein contents tended to linearly increase with increasing soybean hull in the concentrates while total solid content was significantly linearly increased by the addition of SH. Concentrations of ruminal ammonia nitrogen, volatile fatty acids, and pH were unaffected by the treatments. Milk fatty acid contents were also similar in all treatments except for C18:2 and C18:3 that were significantly linearly increased by the addition of SH. The present study suggested that SH can effectively replace high cost starchy ground corn in the concentrates. Levels of SH addition in the concentrate should not be in excess of 20% and SH can replace ground corn up to 100% in the concentrate.**

**Keywords: Soybean hull; lactating dairy cow, milk production, and composition**

## Introduction

Feed, particularly concentrate, is the major cost associated with dairy production in tropical countries. To reduce the cost of concentrate, dairy farmers should find alternative sources of feedstuffs. Soybean hulls are the skins taken off soybean seeds before they are processed for oil and meal. They are a co-product of oil extraction from the soybean. Soybean hulls are a relatively high-energy, medium-protein feed although the laboratory analysis of soybean hulls indicates it is high in fiber but the highly digestible fiber is useful to ruminants. If readily accessible and

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*School of Animal Production Technology, Institute of Agricultural Technology, Suranaree University of Technology, University Avenue, Amphur Muang, Nakhon Ratchasima, Thailand. 30000, Tel.: 66-44-224160, Fax.: 66-44-224150, E-mail: pipat@sut.ac.th*

* *Corresponding author*

priced competitively with other feedstuffs, soybean hulls should be considered in dairy cattle rations. Soybean hulls constitute approximately 5 percent of the original raw soybean weight. Nearly all soybeans are processed by solvent extraction procedures. The solvent extraction process begins with cleaning, cracking with a roller, then removal of the hull from the endosperm by aspiration. Hulls are toasted, ground, and pelleted for marketing. Some hulls may be added back to soybean meal to meet product specifications of either 44 (ruminant) or 48 (non-ruminant) percent protein (Blasi *et al.*, 2000). High dietary levels of cereal grains such as corn, sorghum, and polished rice, which are high in starch, can decrease forage digestibility. Soybean hulls offer an alternative to high-starch grains, as they contain significant levels of digestible fiber and, in many growing diets, can be used as an energy source with a similar value to grains. The objective of this trial was to determine the optimum level of SH inclusion needed to maximize cattle performance in receiving diets for lactating dairy cows.

## Materials and Methods

### Animals and Treatments

Twenty four Holstein Friesian crossbred (>87.5% Holstein Friesian) lactating dairy cows, averaging 16.3 ± 1.4 kg/d of milk, 84 ± 15 days in milk, 42 ± 5 mo old, and 415 ± 20 kg body weight, were blocked by milking days first and then by milk yield, body weight, and age into 2 groups of 12 cows. Cows within each group were further randomly assigned to 3 treatments of 8 cows each. The treatments were control (0% SH), 10% SH and 20% SH in the concentrates. All cows were fed 9 kg of concentrate daily and also received *ad libitum* corn silage (first 6 weeks) or grass silage (last 4 weks), had free access to clean water, were individually housed in a free-stall unit, and individually fed according to treatments. The experiment lasted for 10 weeks of which the first 2 weeks were the adjustment period, followed by 8 weeks of measurement period.

### Measurements, Sample Collection, and Chemical Analysis

All cows were individually housed in a $2 \times 3$ m$^2$ pen and were individually fed 9 kg of experimental concentrate daily, divided into 3 equal meals, at 07.00, 11.30, and 16.30 h. Feed intake was measured on 2 consecutive days weekly and samples of feed were collected for laboratory analyses. At the end of the experimental period, feed samples were composited and subsamples were taken for further chemical analysis. After being dried (60°C) and ground to pass a 1 mm screen in a Wiley mill, feed samples were analyzed in duplicate for dry matter (DM) by drying a 1 g sample in duplicate at 60° C in a conventional oven for 36 h; for ash by burning a 2 g sample at 500°C for 3 h in a muffle furnace; for ether extract; for nitrogen (N) (AOAC, 1995); for neutral detergent fiber with residual ash (NDF, using $\alpha$-amylase and sodium sulfite); for acid detergent fiber (ADF); and for acid detergent lignin (ADL) (Van Soest *et al.*, 1991). Chemical analysis was expressed on the basis of the final DM.

All cows were milked twice a day at 05.00 and 15.00 h. Milk yields were individually recorded daily. Samples of milk from individual cows were collected on 2 consecutive days weekly and then subjected to laboratory analyses. The fat, protein, lactose, solid not fat (SNF), and total solid (TS) contents of the milk were analyzed by Milko Scan (Foss Electric, Hilleroed, Denmark). Live weights of all cows were individually recorded on 2 consecutive days immediately after morning milking at the start and at the end of the experimental period.

### Milk Fatty Acid Analysis

Milk samples were collected from individual cows on day 0, 14, 28, 42, and 56 of the experiment. Milk samples of each period were centrifuged at 2000 g to fat cake and extraction. Lipid extraction followed the procedures described by Hara and Radin (1978), using a volume of 18 ml of hexane and isopropanol (3:2, vol/vol)/g of fat cake. After vortexing, a sodium sulfate solution (6.7%

$NaSO_4$ in distilled $H_2O$) was added at a volume of 12 ml/g of fat cake. The hexane layer was transferred to a tube containing 1 g of $NaSO_4$ and after 30 min. the hexane layer was removed and stored at -20°C until methylation.

Fatty acid methyl esters (FAME) were prepared by the procedure described by Ostrowska *et al.* (2000). The procedure involved that approximately 30 mg of the extracted oil being placed into a 15-ml reaction tube fitted with a teflon-lined screw cap. One and a half ml of 0.5 M sodium hydroxide in methanol was added. The tubes were flushed with nitrogen, capped, heated at 100°C for 5 min with occasional shaking, and then cooled to room temperature. One ml of C17:0 internal standard (2.00 mg/ml in hexane) and 2 ml of 14% boron trifluoride in methanol were added and heated at 100°C for 5 min with occasional shaking. After methylation was completed, 10 ml of deionized water was added. The solution was transferred to a 40-ml centrifuged tube and 5 ml of hexane was added for FAME extraction. The solution was centrifuged at 2,000g, at 10°C for 20 min and then the hexane layer was dried over sodium sulfate and was taken into a vial for analysis by gas chromatography (GC) (Hewlett Packard GCsystem HP6890 A, Hewlett Packard, Avondale, PA) equipped with a 100 m × 0.25 mm fused silica capillary column (SP2560, Supelco Inc, Bellefonte, PA, USA). Injector and detector temperatures were 240°C. The column temperature was kept at 70°C for 4 min, then increased at 13°C /min to 175°C and held at 175°C for 27 min, then increased at 4°C /min to 215°C and held at 215°C for 31 min.

Ruminal fluid (100 ml) was collected, from 4 cows/treatment, through the ventral sac by suction via a polyethylene tube at 0, 2, 4, and 6 h post feeding. The pH of the rumen fluid was immediately determined at the time of sampling by pH meter. Ruminal volatile fatty acids (VFA) and ammonia N were determined from rumen fluid samples taken on 20 ml of rumen fluid and combined with 5 ml 6N HCl, and kept at -20°C until analyzed for VFA and ammonia N. The samples were thawed at 4°C and centrifuged at 3,000 rpm for 15 min. The supernatant fluid was analyzed for ammonia N by Kjeldahl and VFA (acetate, propionate, and butyrate) concentrations were determined by gas chromatography (Hewlett Packard GC system HP6890 A ;, Hewlett Packard, Avondale, PA) equipped with a 30 m × 0.25 mm × 0.25 µm film (DB-FFAP).

### Statistical Analysis

Measurements of intakes, milk production, pH, $NH_3$-N and VFAs were subjected to analysis of variance using PROC GLM and responses to the level of SH were tested using orthogonal polynomial (SAS, 1988). Differences between treatment means were statistically compared using Duncan's New Multiple Range Test (Steel and Torrie, 1980).

## Results and Discussion

Crude fiber (CF), NDF and ADF, and ash increased with increasing SH in the concentrates while non fiber carbohydrate (NFC) decreased with increasing SH in the concentrates (Table 1). This is in agreement with others (Mansfield and Stern, 1994; Elliott *et al.*, 1995; and Ipharraguerre *et al.,* 2002). Total digestible nutrient at maintenance level ($TDN_{1X}$) of the experimental concentrates as calculated according to NRC (2001) ranged from 72.6 - 75.4%, while net energy for lactation at production level ($NE_{LP}$) ranged from 1.66 - 1.73 Mcal/kg of DM. Corn silage had a similar chemical composition and energy concentration to grass silage. Table 2 showed the compositions of fatty acids contained in the experimental diets. All concentrates had similar fatty acid profiles while corn silage also had a similar fatty acid composition to grass silage.

Cows on all diets consumed similar amounts of DM, CP, and net energy for lactation at the production level (Table 3). However, total crude protein intake tended to quadratically increase with increasing SH levels in the concentrates. All cows produced a similar milk yield, 4% fat corrected milk (4%FCM) yield, milk composition yields, and milk compositions (Table 4) except for total solid content that

**Table 1. Chemical compositions of feeds used in the experiment**

| | **Level of soybean hull** | | | **Corn silage** | **Grass silage** |
|---|---|---|---|---|---|
| | **0%** | **10%** | **20%** | | |
| **%DM** | **91.5** | **91.7** | **91.8** | **29.4-** | **26.5** |
| | **-----------------------------% of DM-----------------------------** | | | | |
| CP | 19.70 | 22.40 | 20.50 | 7.80 | 7.50 |
| EE | 2.70 | 2.70 | 2.40 | 1.30 | 1.10 |
| CF | 12.20 | 13.90 | 16.20 | 65.30 | 41.60 |
| Ash | 6.00 | 6.20 | 6.40 | 14.10 | 9.60 |
| NFC | 40.20 | 36.90 | 35.00 | 12.10 | 8.50 |
| NDF | 31.40 | 31.90 | 35.70 | 66.10 | 73.40 |
| ADF | 18.20 | 20.90 | 25.10 | 40.10 | 43.60 |
| ADL | 3.50 | 3.20 | 3.40 | 3.70 | 4.20 |
| NDIN | 2.40 | 2.70 | 2.20 | 0.70 | 0.70 |
| ADIN | 0.80 | 0.90 | 0.70 | 0.60 | 0.50 |
| $TDN_{1X}$ (%) | 74.70 | 75.40 | 72.60 | 50.90 | 53.00 |
| $DE_P$ (Mcal/kg of DM) | 3.09 | 3.12 | 3.04 | 2.37 | 2.37 |
| $ME_P$ (Mcal/kg of DM) | 2.67 | 2.73 | 2.63 | 1.89 | 1.95 |
| $NE_{LP}$ (Mcal/kg of DM) | 1.69 | 1.73 | 1.66 | 1.14 | 1.18 |
| Protein degradability (*dg*) | 0.65 | 0.69 | 0.67 | 0.52 | 0.51 |

1/ $TDN_{1X}$(%) = tdNFC + tdCP + (tdFA x 2.25) + tdNDF – 7)

2/ $DE_{1X}$(Mcal/kg) = [(tdNFC/100) x 4.2]+[(tdNDF/100) x 4.2]X[(tdCP/100) x 5.6]+[(FA/100) x 9.4] – 0.3

3/ $DE_P$(Mcal/kg) = {[($TDN_{1X}$ – [(0.18 x $TDN_{1X}$) – 10.3]) x Intake]/ $TDN_{1X}$} x $DE_{1X}$

4/ $ME_P$(Mcal/kg) = [1.01 x ($DE_p$) – 0.45] + [0.0046 x (EE – 3)]

5/ $NE_{LP}$(Mcal/kg) = [0.703 x $ME_p$] – 0.19 (EE≤ 3%)

5/ $NE_{LP}$(Mcal/kg) = ([0.703 x $ME_p$] – 0.19) + [(0.097 x $ME_p$)/97] (EE< 3%)

$TDN_{1X}$ = total digestible nutrient at maintenance level.
$DE_P$ = digestible energy at production level.
$ME_P$ = metabolizable energy at production level.
$NE_{LP}$ = net energy for lactation at production level.

**Table 2. Fatty acid compositions of feeds used in the experiment**

| | **Level of soybean hull** | | | **Corn silage** | **Grass silage** |
|---|---|---|---|---|---|
| | **0%** | **10%** | **20%** | | |
| | **----------------------% of total fatty acid---------------------** | | | | |
| C8:0 | 1.39 | 1.30 | 1.39 | ND | ND |
| C10:0 | 1.52 | 1.53 | 1.57 | ND | ND |
| C12:0 | 26.24 | 27.17 | 26.07 | 1.35 | 2.25 |
| C14:0 | 9.67 | 10.02 | 9.45 | 1.38 | 1.33 |
| C15:0 | ND | ND | ND | 1.95 | 2.55 |
| C16:0 | 18.53 | 20.33 | 18.46 | 26.45 | 24.13 |
| C18:0 | 3.83 | 4.23 | 3.98 | 5.41 | 3.81 |
| C18:1n9c | 22.57 | 23.65 | 20.88 | 7.64 | 3.67 |
| C18:2n6c | 14.96 | 17.03 | 15.84 | 21.04 | 20.32 |
| C20:0 | 0.33 | ND | ND | 1.78 | 2.14 |
| C18:3n3 | 0.97 | 1.80 | 2.37 | 24.50 | 35.03 |
| C22:0 | ND | ND | ND | 2.30 | 1.60 |
| C24:0 | ND | ND | ND | 6.20 | 3.81 |

ND = not detectable

linearly increased with increasing SH in the concentrate. However, fat and protein contents tended to be linearly increased when the level of SH addition in the concentrates increased. Elliott *et al.* (1995); Mansfield and Stern (1994); Pantoja *et al.* (1994); and Ipharraguerre *et al.* (2002) found no significant differences in DMI, milk yield, and milk composition yields when ground corn was replaced by SH in the concentrates. Cows which consumed the 10% SH diet gained weight while those cows which consumed the 0% SH and 20% SH diets lost

**Table 3. Dry matter (DM), crude protein (CP), and net energy for lactation ($NE_{LP}$) intakes of experimental cows**

| | Level of soybean hull | | | SEM | *p*-value | Contrast | |
|---|---|---|---|---|---|---|---|
| | 0% | 10% | 20% | | | L | Q |
| DM intake (kg/d) | | | | | | | |
| Concentrate | 8.2 | 8.3 | 8.3 | - | - | - | - |
| Silage | 6.9 | 6.8 | 7.0 | 0.35 | 0.936 | 0.880 | 0.744 |
| Total | 15.1 | 15.1 | 15.3 | 0.35 | 0.930 | 0.836 | 0.754 |
| CP intake (g/d) | | | | | | | |
| Concentrate | 1,615 | 1,837 | 1,701 | - | - | - | - |
| Silage | 531 | 524 | 539 | 26.8 | 0.816 | 0.767 | 0.577 |
| Total | 2,146 | 2,361 | 2,240 | 18.2 | 0.092 | 0.737 | 0.033 |
| $NE_{LP}$ intake (Mcal/d) | | | | | | | |
| Concentrate | 13.86 | 14.19 | 13.78 | - | - | - | - |
| Silage | 8.00 | 7.89 | 8.12 | 0.42 | 0.937 | 0.883 | 0.745 |
| Total | 21.86 | 22.08 | 21.90 | 0.42 | 0.854 | 0.864 | 0.597 |

SEM = standard error of the mean; $NE_{LP}$ = net energy for lactation; L = linear; Q = quadratic

**Table 4. Milk yield, milk composition yield, milk compositions, initial weight, final weight, and live weight (LW) change of experimental cows**

| | Level of soybean hull | | | SEM | *p*-value | Contrast | |
|---|---|---|---|---|---|---|---|
| | 0% | 10% | 20% | | | L | Q |
| Milk yield (kg/d) | 14.80 | 15.50 | 14.20 | 0.95 | 0.697 | 0.720 | 0.446 |
| 4% FCM (kg/d) | 14.80 | 16.50 | 15.70 | 0.82 | 0.392 | 0.479 | 0.244 |
| Fat yield (g/d) | 598.00 | 699.00 | 692.00 | 35.00 | 0.125 | 0.120 | 0.175 |
| Protein yield (g/d) | 477.00 | 516.00 | 477.00 | 28.00 | 0.565 | 0.936 | 0.293 |
| Lactose yield (g/d) | 697.00 | 758.00 | 687.00 | 52.00 | 0.624 | 0.954 | 0.338 |
| SNF yield (g/d) | 1,277.00 | 1,381.00 | 1,264.00 | 86.00 | 0.610 | 0.927 | 0.328 |
| Total solid yield (g/d) | 1,863.00 | 2,080.00 | 1,955.00 | 114.00 | 0.464 | 0.676 | 0.247 |
| Fat (%) | 4.04 | 4.51 | 4.87 | 0.25 | 0.061 | 0.020 | 0.850 |
| Protein (%) | 3.22 | 3.33 | 3.36 | 0.06 | 0.097 | 0.035 | 0.749 |
| Lactose (%) | 4.71 | 4.89 | 4.84 | 0.09 | 0.417 | 0.339 | 0.362 |
| Solid not fat (%) | 8.63 | 8.91 | 8.90 | 0.34 | 0.104 | 0.069 | 0.253 |
| Total solid (%) | 12.59$^{c}$ | 13.42$^{b}$ | 13.77$^{a}$ | 0.11 | 0.008 | 0.003 | 0.435 |
| Initial weight (kg) | 417.00 | 417.00 | 410.00 | 19.00 | 0.958 | 0.801 | 0.884 |
| Final weight (kg) | 415.00 | 419.00 | 398.00 | 18.00 | 0.697 | 0.512 | 0.597 |
| LW change (g/d) | -63.00 | +50.00 | -83.00 | 177.00 | 0.188 | 0.185 | 0.201 |

SEM = standard error of the mean; FCM = fat corrected milk; L = linear; Q = quadratic weight.

Although there were no significant differences in milk composition, milk fat, and milk protein contents of the cows fed the 10% and 20% SH diets, these tended to be higher than for those cows fed the control diet. Increasing energy intake is the most reliable means of increasing milk protein content (Sutton, 1989). In the present study, the cows on the 10% SH diet tended to consume more $NE_{LP}$ than cows on the control diet. Furthermore, the tendency towards reductions in ruminal $NH_3$-N of the 10% SH cows at 4 h and 6 h post feeding probably reflected the high capture of $NH_3$-N by rumen microorganisms which may result in higher microbial protein being produced. This resulted in a tendency of a higher protein content in the 10% SH cows than the control cows.

Similar results have also been reported; Bernard and McNeill (1991) substituted soybean hulls for two-thirds of the corn and a portion of the soybean meal in a control diet and observed that intake, milk production, and milk components were not different from those of cows fed the control diet. In another study, Coomer *et al.* (1993) altered the level of nonstructural carbohydrate by replacing corn and wheat in the control diet with corn gluten feed and soybean hulls. Dry matter intake, milk production, and milk components were unaffected by dietary treatment. Thus, soybean hulls can effectively replace a portion of the corn and soybean meal of dairy diets. Based on the data available, 10 to 20% of the concentrate portion of the diet has

**Table 5. Fatty acid composition of experimental cows' milk (mg/g fat)**

| | Level of soybean hull | | | SEM | *p*-value | Contrast | |
|---|---|---|---|---|---|---|---|
| | 0% | 10% | 20% | | | L | Q |
| C4:0 | 8.040 | 8.89 | 9.69 | 0.11 | 0.335 | 0.146 | 0.955 |
| C6:0 | 6.690 | 8.09 | 7.87 | 0.74 | 0.351 | 0.257 | 0.369 |
| C8:0 | 4.230 | 5.21 | 5.01 | 0.46 | 0.279 | 0.227 | 0.291 |
| C10:0 | 10.070 | 12.56 | 11.48 | 1.10 | 0.254 | 0.345 | 0.172 |
| C11:0 | 1.310 | 1.47 | 1.52 | 0.15 | 0.626 | 0.364 | 0.771 |
| C12:0 | 29.390 | 33.74 | 31.94 | 2.30 | 0.399 | 0.274 | 0.426 |
| C13:0 | 0.850 | 1.16 | 1.12 | 0.13 | 0.633 | 0.524 | 0.483 |
| C14:0 | 72.710 | 80.13 | 78.39 | 0.78 | 0.505 | 0.395 | 0.428 |
| C14:1 | 7.500 | 7.80 | 9.25 | 0.93 | 0.477 | 0.261 | 0.668 |
| C15:0 | 5.110 | 5.93 | 5.85 | 0.33 | 0.124 | 0.091 | 0.231 |
| C16:0 | 204.640 | 207.02 | 226.73 | 11.16 | 0.350 | 0.191 | 0.545 |
| C16:1 | 10.540 | 10.60 | 16.76 | 2.09 | 0.396 | 0.237 | 0.510 |
| C18:0 | 44.170 | 47.45 | 46.83 | 4.25 | 0.881 | 0.705 | 0.748 |
| C18:1n9t | 6.990 | 4.83 | 8.32 | 1.39 | 0.173 | 0.463 | 0.085 |
| C18:1n9c | 103.920 | 116.63 | 126.06 | 9.37 | 0.275 | 0.115 | 0.892 |
| C18:2n6t | 0.300 | 0.53 | 0.54 | 0.08 | 0.044 | 0.026 | 0.212 |
| C18:2n6c | 5.900[b] | 7.11[a] | 7.36[a] | 0.64 | 0.246 | 0.121 | 0.548 |
| C18:3n3 | 0.740 | 1.06 | 1.16 | 0.13 | 0.038 | 0.015 | 0.448 |
| C20:0 | 0.760[b] | 0.75[a] | 0.71 | 0.07 | 0.917 | 0.708 | 0.868 |
| CLAa | 2.890 | 2.50 | 2.63 | 0.35 | 0.774 | 0.635 | 0.600 |
| C20:2n6 | 0.200 | 0.49 | 0.45 | 0.05 | 0.224 | 0.221 | 0.214 |
| C22:4n6 | 0.750 | 1.08 | 0.97 | 0.10 | 0.420 | 0.081 | 0.054 |
| C24:0 | 0.721[b] | 1.09[a] | 0.55[a] | 0.22 | 0.192 | 0.578 | 0.086 |

SEM = standard error of the mean; L = linear; Q = quadratic

CLAa = cis-9, trans-11octadecadienoic acid been replaced successfully with soybean hulls. In the present study, increasing SH in the concentrates caused linear increases in C18:3n3 fatty acid in milk (Table 5). Increases in C18:3n3 fatty acid in milk reflected the increases in C18:3n3 fatty acid in the concentrate with increasing SH (Table 2).

There was a tendency towards a quadratic reduction in ruminal $NH_3$-N at 4 h post feeding with increasing SH in the concentrates, while propionate production at 6 h post feeding tended to linearly and quadratically increase with the increasing SH level in the concentrates in the present study (Table 6). A tendency of a reduction in ruminal $NH_3$-N at 4 h post feeding with increasing SH probably was caused by increasing fiber fermentation. Since, $NH_3$-N concentrations are a result of production and utilization, the exact causes of $NH_3$-N reduction are difficult to assess. Depression of $NH_3$-N concentrations may occur from increased fiber fermentation because $NH_3$-N is the primary N source of fiber-degrading bacteria (Nocek and Russell, 1988). A tendency of increasing propionate production at 6 h post feeding with increasing SH in the concentrate probably resulted from a more digested fiber from SH yielding propionate. Ipharraguerre and Clark (2003) indicated that replacing ground corn with SH in dairy diets to supply from 5 to 25% of the dietary DM usually increased the molar proportion of propionate in the ruminal fluid.

When combining the data for milk yield and body weight (BW) change, it was possible

**Table 6. Concentrations of ammonia nitrogen, volatile fatty acids, and pH in ruminal fluid of experimental cows**

| | Level of soybean hull | | | SEM | *p*-value | Contrast | |
|---|---|---|---|---|---|---|---|
| | 0% | 10% | 20% | | | L | Q |
| pH | | | | | | | |
| Hour 0 | 6.99 | 7.01 | 6.94 | 0.07 | 0.799 | 0.760 | 0.655 |
| Hour 2 | 6.92 | 6.94 | 6.99 | 0.05 | 0.672 | 0.452 | 0.397 |
| Hour 4 | 6.76 | 6.82 | 6.79 | 0.15 | 0.962 | 0.882 | 0.846 |
| Hour 6 | 6.71 | 6.77 | 6.77 | 0.10 | 0.928 | 0.829 | 0.901 |
| $NH_3N$ | ----------(mg/dl)---------- | | | | | | |
| Hour 0 | 7.98 | 8.14 | 10.16 | 0.58 | 0.815 | 0.118 | 0.312 |
| Hour 2 | 13.47 | 12.56 | 13.96 | 0.87 | 0.602 | 0.724 | 0.394 |
| Hour 4 | 11.82 | 9.13 | 12.71 | 0.43 | 0.051 | 0.268 | 0.028 |
| Hour 6 | 8.93 | 8.16 | 9.24 | 0.18 | 0.097 | 0.293 | 0.055 |
| Acetate; $C_2$ | --------(mol/100mol)-------- | | | | | | |
| Hour 0 | 76.17 | 76.62 | 77.45 | 0.67 | 0.519 | 0.312 | 0.842 |
| Hour 2 | 75.19 | 74.87 | 76.40 | 0.56 | 0.393 | 0.255 | 0.521 |
| Hour 4 | 76.16 | 73.75 | 75.39 | 0.74 | 0.686 | 0.541 | 0.601 |
| Hour 6 | 77.23 | 75.55 | 76.07 | 0.48 | 0.326 | 0.226 | 0.396 |
| Propionate; $C_3$ | --------(mol/100mol)-------- | | | | | | |
| Hour 0 | 15.14 | 16.01 | 15.61 | 0.59 | 0.647 | 0.630 | 0.472 |
| Hour 2 | 16.77 | 16.59 | 16.98 | 0.12 | 0.750 | 0.707 | 0.560 |
| Hour 4 | 15.13 | 16.61 | 16.26 | 0.61 | 0.384 | 0.323 | 0.343 |
| Hour 6 | $13.76^b$ | $15.30^a$ | $15.09^a$ | 0.19 | 0.048 | 0.038 | 0.063 |
| Butyrate; $C_4$ | --------(mol/100mol)-------- | | | | | | |
| Hour 0 | 8.94 | 8.51 | 7.36 | 0.61 | 0.519 | 0.312 | 0.842 |
| Hour 2 | 9.43 | 9.19 | 8.07 | 0.55 | 0.393 | 0.255 | 0.521 |
| Hour 4 | 9.17 | 9.52 | 8.55 | 0.12 | 0.686 | 0.541 | 0.601 |
| Hour 6 | 8.70 | 8.34 | 9.09 | 0.29 | 0.326 | 0.226 | 0.396 |

SEM = standard error of the mean, L = linear; Q = quadratic

**Table 7. Estimates of the distribution of net energy intake**

| | Level of soybean hull | | | SEM | *p*-value | Contrast | |
|---|---|---|---|---|---|---|---|
| | 0% | 10% | 20% | | | L | Q |
| $NE_{LP}$ intake (Mcal/d) | 21.90 | 22.10 | 21.90 | 0.42 | 0.854 | 0.864 | 0.597 |
| $NE_{LM}$ (Mcal/d) | 7.40 | 7.40 | 7.20 | 0.24 | 0.855 | 0.650 | 0.752 |
| $NE_{LG}$ (Mcal/d) | -1.00 | +0.70 | -1.40 | 0.57 | 0.422 | 0.536 | 0.250 |
| $NE_{LL}$ (Mcal/d) | 11.00 | 12.10 | 11.50 | 0.33 | 0.240 | 0.337 | 0.182 |
| $NE_{LR}$ (Mcal/d) | 17.40 | 20.20 | 17.30 | 0.80 | 0.685 | 0.470 | 0.637 |
| Efficiency of $NE_{LP}$ utilization | 0.79 | 0.91 | 0.79 | 0.04 | 0.516 | 0.266 | 0.808 |

$NE_{LP}$: net energy for lactation at production level.
$NE_{LM}$: net energy requirement for maintenance = $0.08 \times LW^{0.75}$
$NE_{LG}$: net energy requirement for gain = reserve energy × (0.64/0.75)
$NE_{LG}$: net energy requirement for loss = reserve energy × (0.82)
$NE_{LL}$: net energy requirement for lactation = 0.0929 × % fat + 0.0547 × % CP + 0.0395 × % lactose.
$NE_{LR}$: net energy retention.
Efficiency of $NE_L$ utilization = $NE_{LR}/NE_{LP}$ intake.
SEM = standard error of the mean.
L = linear; Q = quadratic

to compare the effect of different rations on the apparent utilization of the net energy for lactation at production ($NE_{LP}$) intake (Table 7). Both groups of cows consumed similar $NE_{LP}$, therefore the partitioning of energy between milk productions was also similar.

All groups of cows had a considerable supply of $NE_{LP}$ but the milk yields were lower than would have been expected from $NE_{LP}$ intakes. The respective intakes of 21.9, 22.1, and 21.9 Mcal daily by cows in the control, 10% SH, and 20% SH groups, in theory, should be able to produce approximately 19.5, 18.8, and 18.2 kg of milk/d respectively. The lower milk yield than what would be expected from the $NE_{LP}$ available could be attributed to the probable underestimates of the net energy for lactation at maintenance ($NE_{LM}$) for dairy cows in the tropics. Since dairy cows in the tropics are fed lower quality feeds than cows in the United States, the use of the equation suggested by the NRC (2001) might be inappropriate. AAC (1990) recommended that dairy cattle consuming feeds containing energy lower than 10 MJ metabolizable energy (ME)/kg DM needed more energy for maintenance. The present study used a net energy maintenance value of 0.08 Mcal/kg $BW^{0.75}$ for predicting $NE_{LM}$. If the hypothesis by AAC (1990) is true, with the assumption that the average net energy values of milk and BW change are unaffected by the quality of feeds as in the case of $NE_{LM}$, the average net energy maintenance value of 0.120 Mcal/ kg $BW^{0.75}$ should be used in this study. This is approximately 50% higher than the NRC (2001) recommendation. Suksombat and Mernkratoke (2005), and Suksombat and Junpanichcharoen (2005) suggested that, in the tropics, the average net energy maintenance value of 0.083 and 0.106 Mcal/kg $BW^{0.75}$, respectively, would be more appropriate than the value of 0.08 Mcal/kg $BW^{0.75}$ recommended by NRC (2001). Before a conclusion can be reached, further research is needed.

The estimated supplies of rumen degradable protein (RDP) and rumen undegradable protein (RUP) to the cows can be calculated using the protein degradability values of each feed (determined by the nylon bag technique; Table 8; NRC, 2001). All cows consumed similar RDP and RUP, however, cows on 10% SH received adequate RDP but

**Table 8. The estimated supply of rumen degradable protein and rumen undegradable protein**

| | Level of soybean hull | | | SEM | *p*-value | Contrast | |
|---|---|---|---|---|---|---|---|
| | 0% | 10% | 20% | | | L | Q |
| $RDP_{req}$ | 1,498 | 1,500 | 1,480 | 29 | 0.878 | 0.678 | 0.771 |
| $RDP_{sup}$ | 1,325 | 1,541 | 1,410 | 37 | 0.985 | 0.843 | 0.724 |
| Deficit/Surplus | -172 | +41 | -70 | 36 | 0.623 | 0.625 | 0.547 |
| $MCP_{sup}$ | 1,273 | 1,275 | 1,258 | 25 | 0.871 | 0.670 | 0.765 |
| $MP_R$ | 1,287 | 1,338 | 1,285 | 50 | 0.732 | 0.984 | 0.436 |
| $RUP_{req}$ | 759 | 854 | 773 | 75 | 0.665 | 0.902 | 0.377 |
| $RUP_{sup}$ | 828 | 829 | 823 | 13 | 0.942 | 0.781 | 0.844 |
| Deficit/Surplus | +69 | -25 | +50 | 69 | 0.636 | 0.852 | 0.357 |

SEM = standard error of the mean; $RDP_{req}$ = ; $RDP_{sup}$ = CP intake x *dg*; $MP_R$ = ; $RUP_{req}$ = ; $RUP_{sup}$ = .CP intake - $RDP_{sup}$, L = linear; Q = quadratic

inadequate RUP while cows on 0% and 20% SH consumed inadequate RDP but adequate RUP. The deficit in RDP supply relative to demand would have reduced microbial protein synthesis and thus a low quantity of microbial protein would have reached the small intestine. The present study indicated that replacement of soybean hull for ground corn did not affect milk yield, milk composition, fatty acid composition of milk, and body weight change of lactating dairy cow.

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