ELSEVIER
Livestock Production Science 63 (2000) 131–140
LIVESTOCK PRODUCTION SCIENCE
www.elsevier.com/locate/livprodsci

Effect of amount of undegradable crude protein in the diets of high-yielding dairy cows on energy balance and reproduction

I. Bruckental[a,*], M. Holtzman[a], M. Kaim[a], Y. Aharoni[a], S. Zamwell[b], H. Voet[b], A. Arieli[b]

[a]*Institute of Animal Science, Agricultural Research Organization, The Volcani Center, P.O. Box 6, Bet Dagan 50250, Israel*
[b]*Department of Animal Science, The Hebrew University of Jerusalem, Faculty of Agricultural, Food and Environmental Sciences, Rehovot 76100, Israel*

Received 23 December 1998; received in revised form 22 April 1999; accepted 10 May 1999

Abstract

This trial was designed to investigate effects of the amount of dietary undegradable crude protein (CP) and the ratio of degradable organic matter to degradable CP in the diets of high-yielding dairy cows on milk yield, energy balance and fertility during the first three months postpartum. Forty-five Israeli Holstein cows were assigned to three dietary treatments at 2 d postpartum. Dietary treatments were (1) 16.7% CP, of which 32% was undegradable (control); (2) 16.7% CP, of which 38% was undegradable; and (3) 18.0% CP, of which 35% was undegradable. Corn gluten meal (CGM) was added to diets 2 and 3 in order to increase undegradability. Cows were fed in groups, and diets were offered as a total mixed ration. Intakes of dry matter (DMI) and CP (kg/d) were 23.8 and 3.975, 21.4 and 3.574, and 20.4 and 3.672, for cows on diets 1, 2 and 3, respectively. No significant differences among the three treatments were found for milk yield, milk protein concentration, milk fat, or protein and lactose yields. Control cows lost 35.0 kg of body weight (BW) during the first 27.2 d postpartum, and then started gaining weight. At approximately day 70 the control cows attained their calving weight. Cows on diets 2 and 3 lost 55 kg of BW during 45 d postpartum and, by the end of the trial, these cows still had not attained their calving weight. Change in body condition score (BCS) during the experimental period revealed the same trends. Mean concentrations (mg/100 ml) of ammonia N in ruminal fluids and concentrations of plasma urea N were 14.0 and 20.3, 12.7 and 21.2, and 14.7 and 21.3 for cows on diets 1, 2 and 3, respectively. No significant differences among treatments were detected for any reproduction parameter. It was concluded that the differences between control cows and cows on diets 2 and 3 in DMI, BW and BCS during the first period postpartum cannot be attributed to the level of dietary undegradable CP only but to a more specific effect of CGM.

Keywords: Dairy cows; Gluten meal; Undegradable CP; Energy balance; Insulin

1. Introduction

Fertility in high-producing dairy herds has been decreasing in recent decades. This phenomenon is

*Corresponding author. Tel.: +972-8-9484-447; fax: +972-8-9475-075.
E-mail address: brucken@agri.huji.ac.il (I. Bruckental)

0301-6226/00/$ – see front matter
PII: S0301-6226(99)00124-4

obvious in the Israeli herd (Ron et al., 1984) as well as in other countries (Lamming, 1998). Butler and Smith (1989) found a negative correlation between milk yield and conception rate. Ostergaard et al. (1990) have suggested that the genetic breeding program of a dairy herd is focused on high milk yields only, without a parallel concern for increased feed consumption. As a result, the partitioning of absorbed metabolites was directed primarily toward milk yield, and deficiency, mainly of energy, was developed in other essential metabolic pathways (Nebel and McGillard, 1993).

Dairy cows ovulate even if they are in a negative energy balance. However, ovarian activity is apparent earlier in cows with an improved energy status (Staples et al., 1990). Sklan et al. (1991) improved the fertility of high-yielding cows by offering diets supplemented with calcium soaps of fatty acids. Similar diets in other studies (Carroll et al., 1990; Spicer et al., 1993) failed to improve fertility. The examination of dietary ingredients such as protein source and concentration would appear to be desirable if the aim is ultimately to improve feed intake (Dhiman and Satter, 1993). The effect of dietary protein on feed intake is explained partially by the effect of protein on microbial fermentation and digestion and by the effect of the amino acid profile on whole animal metabolism and yield (Garnsworthy and Cole, 1990). However, there is still a lack of information regarding composition and amount of supplementary crude protein (CP).

According to the NRC (1989), undegradable (UD) CP levels in lactating cow diets ranges between 54 and 63 g/kg DM. The present work was designed to determine the effect of improved protein availability, via the higher UDCP concentrations, on dry matter intake (DMI), milk yield, energy balance and fertility of high-yielding dairy cows during the first three months postpartum.

2. Materials and methods

2.1. Animals

Forty-five Israeli Holstein cows (parity ≥ 2) were assigned to three dietary treatments at 2 d postpartum, according to expected calving date, parity number, milk yield during the previous lactation and body weight (BW). The cows were maintained in the trial for at least three months. Cows were milked three times daily, at 06:00, 14:00 and, 20:00 h. Milk yield and BW were recorded at each milking by the Afimilk system (S.A.E. AFIKIM, Kibbutz Afikim, Israel). Body condition was scored once a week. Milk samples from three consecutive milkings were collected every 10 days and analyzed for fat, protein and lactose by the infrared procedure at the Israel Cattle Association Laboratories (Bitan Aharon, Israel). Sixty days after the beginning of the experiment, ruminal fluid and jugular blood samples were taken from all cows. Rumen samples were taken with a stomach tube. Sampling was done before the first morning meal and 4 and 8 h later. Ruminal fluid samples were kept in tubes containing 0.2 ml mercury chloride.

2.2. Diets

Diets were formulated to contain 30% forage on a DM basis and differed mainly in dietary CP and UDCP contents (Table 1). Diet 1 the control diet, contained 167 g/kg CP, of which 320 g/kg was UDCP. Diet 2 contained 167 g/kg CP, of which 380 g/kg was UDCP. Diet 3 contained 180 g/kg CP, of which 350 g/kg was UDCP. The UDCP content of diet 3 was the same as that of diet 2, and the rumen degradable CP (RDCP) content was the same as in the control diet. Corn gluten meal was added to diets 2 and 3 in order to increase undegradability. Ruminal degradabilities of organic matter (OM) and CP contents of the dietary ingredients, as assessed by the dacron bag technique (Ørskov and McDonald, 1979), are presented in Table 2. When ingredient additivity of ruminal degradation is assumed, the resultant ratios of ruminally degradable OM to RDCP in diets 1, 2 and 3 were 4.5, 5.1 and 4.5, respectively.

Cows were group fed. The diets were fed as a TMR at 10:00 h for ad libitum intake. The feed was moved close to the cows three times a day. Daily DM offered of each group and feed refused were recorded. Diets were sampled once weekly and orts were sampled daily; a representative sample of orts was analyzed for DM, CP and neutral-detergent fiber (NDF).

Table 1
Ingredients of experimental diets

Ingredients (g/kg DM)	Diet[d]		
	1	2	3
Corn gluten meal[a]	18.0	43.0	41.0
NPN mix[b]	6.9	2.2	7.4
Milo grain	12.0	. . .	. . .
Barley grain	222.0	222.0	222.0
Wheat grain	68.0	62.0	67.0
Corn grain	30.0	36.0	36.0
Wheat bran	133.0	133.0	133.0
Soybean meal	27.0	22.0	27.0
Rapeseed meal	44.0	44.0	44.0
Whole cottonseeds	46.0	46.0	46.0
Citrus pulp	76.0	76.0	76.0
Wheat silage	97.0	97.0	97.0
Corn silage	117.0	117.0	117.0
Vetch hay	30.0	30.0	30.0
Oat hay	52.0	52.0	52.0
Oil	3.6	. . .	1.1
$CaCO_3$	16.0	16.0	16.0
NaCl	4.5	4.5	4.5
Vitamins and minerals[c]	0.7	0.7	0.7

[a] Contained 60% of CP.
[b] Non-protein nitrogen. Contained (g/kg) 500 ground milo grain, 333 urea and 167 $(NH_4)_2SO_4$. Calculated to supply 1270 g/kg of CP.
[c] Contained $16 \cdot 10^6$ IU of vitamin A, $3.2 \cdot 10^6$ IU of vitamin D, $16 \cdot 10^6$ IU of vitamin E, 48 g of Mo, 48 g of Zn, 48 g of Fe, 19.2 g of Cu, 3.4 g of I, 0.32 g of Co and 0.48 g of Se.
[d] No. 1, 16.7% dietary CP, of which 32% was undegradable (control); No. 2, 16.7% CP, of which 38% was undegradable; and No. 3, 18.0% CP, of which 35% was undegradable.

Table 2
Chemical composition (g/kg of DM) of experimental diets

	Diet[b]		
	1	2	3
OM	889	903	897
CP	167	167	180
UDCP[a]	52	63	64
RDCP[a]	115	103	116
RDOM[a]	522	522	522
NDF	345	345	345
Ether extract	75	45	53
NE_L (Mcal/kg)	1.72	1.72	1.72
RDOM/RDCP	4.5	5.1	4.5

[a] UDCP = Undegradable CP; RDCP = rumen degradable CP; RDOM = rumen degradable OM.
[b] See footnote d in Table 1.

2.3. Reproductive management

The cows were examined by a veterinarian during the first week after calving. Following this examination, cows that were diagnosed to have a retained placenta, metritis, or other health problems were given appropriate medical treatment. Blood for progesterone analysis was sampled three times weekly, starting 3 d postpartum and continuing until first insemination. First postpartum ovulation was defined as the first day after calving when plasma progesterone concentration reached at least 1 ng/ml. Estrus detection was performed by an automated pedometer system (S.A.E. AFIKIM) and by visual observation during two 30-min periods daily, at 09:00 and 15:00 h. Insemination was commenced 60 d after calving. Cows were inseminated at 11:00 h. Pregnancy was diagnosed 45 d following insemination by rectal palpation.

2.4. Chemical analyses

Chemical analyses were performed on dry feed samples that had been ground using a 2-mm mill. Dry matter was assayed after samples were dried at 105°C for 12 h; corn silage and citrus pulp were first dried at 60°C for 48 h. OM was determined after ashing at 600°C for 2 h. Crude protein was analysed using a Kjeldhal autoanalyser (Tecator, Hoganas, Sweden). The NDF content was determined according to the method of Van Soest et al. (1991). In situ degradabilities of OM and CP in dietary feeds and the kinetics of their degradation in the rumen were determined following the method of Ørskov and McDonald (1979) and as described by Arieli et al. (1989). The fractional rate of particulate outflow from the rumen was assumed to be 6.5%/h. Volatile fatty acids (VFAs) in ruminal fluid that had been centrifuged were assessed by gas–liquid chromatography (Model 5890; Hewlett-Packard, Avondale, PA, USA) on 0.3% Carbovax 20M with 0.1% phosphoric acid (Supelco, Bellefonte, PA, USA), and ammonia was determined by the phenol procedure (Tagari, 1969). Blood was centrifuged, and the plasma was separated and analyzed for urea (Tagari, 1969). Glucose was determined by a Beckman Glucose Analyzer 2 (Fullerton, CA, USA), and plasma insulin and plasma progesterone were determined using radioimmunoassay kits (Diagnostic Products, Los Angeles, CA, USA).

2.5. Calculations and statistical analyses

Data were statistically analysed using the GLM procedure of SAS (1985) to examine the effect of cow, parity number, milk yield during previous lactation, BW and treatment on performance parameters. Comparison between control and CGM-supplemented diets (1 vs. 2 and 3) was tested using nonorthogonal contrast. Averages of NH_3 N and VFAs in ruminal fluids and of urea N in plasma for samples taken before the first morning meal and 4 and 8 h later, were used for comparing the effect of diet. The repeated measures analysis of variance (ANOVA) was used for these metabolites. Reproductive parameters were compared by *t* test. Statistical difference was determined at $P < 0.10$.

3. Results

Mean feed consumption and milk yield and composition are given in Table 3. Mean DMI of the control cows and cows fed diets 2 and 3 were 23.8, 21.4 and 20.4 kg/d, respectively. Accordingly, net energy (NE) intake of the control cows and cows fed diets 2 and 3 was 40.9, 36.8 and 35.1 Mcal/d, respectively. Crude protein and UCP intakes of control cows and of cows fed diets 2 and 3 were 4.0 and 1.2, 3.6 and 1.4, and 3.7 and 1.3 kg/d, respectively. No significant differences among the three diets were found for milk yield and milk fat, protein and lactose concentrations or yields (Table 3). Milk yield curves are described in Fig. 1a. Data for BW and body condition score (BCS) are presented in Table 4, and changes in BW and BCS of cows during the trial period are described in Fig. 1b and c, respectively. The control cows lost 35.0 kg during the first 27.2 d (1.29 kg/d) postpartum, and then started gaining weight. By approximately day 70 these cows attained their calving weight. Cows fed diet 2 lost 54.0 kg of BW during 44.8 d (1.21 kg/d) postpartum, and by the end of the trial the cows still had not attained their calving weight. Cows fed diet 3 lost 55.0 kg BW during 44.4 d (1.24 kg/d; $P <$ 0.164) and, by the end of the trial these cows still had not attained their calving weight. Changes in BCS during the trial period expressed the same trend as BW (Table 4).

Mean ammonia N concentrations in ruminal fluids

Table 3
Mean feed consumption and least-squares means of milk yield and composition during 90 d of the trial period

	Diet[c]			SD	$P > F$	Contrast 2 + 3 vs. 1
	1	2	3			
DMI (kg/d)	23.8	21.4	20.4			
CP intake (kg/d)	3.975	3.574	3.672			
RDCP[a] intake (kg/d)	2.737	2.226	2.366			
UDCP[a] intake (kg/d)	1.238	1.348	1.306			
NE_l intake (Mcal/d)	40.9	36.8	35.1			
Milk yield (kg/d)	38.7	37.8	37.2	3.54	0.820	0.713
Milk fat:						
%	3.23	3.31	3.07	0.39	0.196	0.187
Kg/d	1.279	1.289	1.197	0.195	0.383	0.230
Milk protein:						
%	2.99	2.91	2.89	0.18	0.323	0.863
Kg/d	1.148	1.102	1.073	0.108	0.529	0.620
Milk lactose:						
%	4.39	4.49	4.54	0.20	0.286	0.608
Kg/d	1.695	1.683	1.690	0.174	0.993	0.890
Milk energy[b] (Mcal/d)	25.4	24.9	23.9	2.75	0.720	0.650

[a] RDCP = Degradable CP; UDCP = undegradable CP.
[b] Milk energy was calculated according to Tyrrel and Reid (1965).
[c] See footnote d in Table 1.

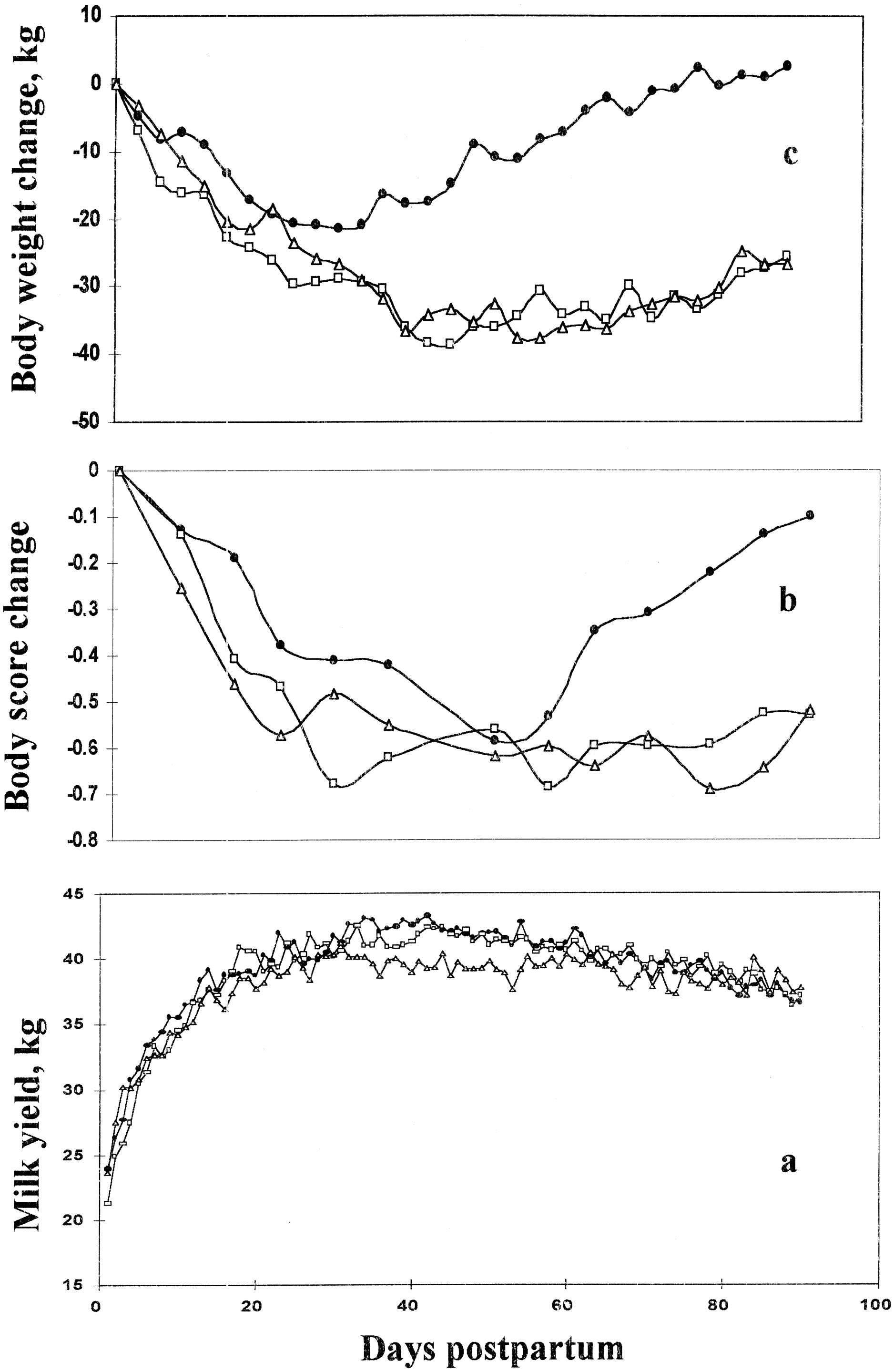

Fig. 1. Curves of milk yield (a) and changes in BW (b) and body condition score (BCS; c) of cows fed the control diet No. 1 (●), the diet containing 16.7% dietary CP, No. 2 (38% of which was undegradable; □), and the diet containing 18.0% dietary CP No. 3 (35% of which was undegradable; △) throughout the trial.

Table 4
Least-squares means for bodyweight (BW) and body condition score (BCS) during 90 d of the trial period

	Diet[c]			SD	$P>F$	Contrast 1 vs. 2 + 3
	1	2	3			
Initial BW[a] (kg)	613	609	602	57.4	0.910	0.677
Minimal BW (kg)	578	555	547	46.9	0.182	0.128
Days to minimal BW[b]	27.4	44.8	44.4	23.6	0.098	0.032
BW loss (kg)	36.4	54.3	54.2	28.1	0.164	0.059
BW 90 d postpartum	616	583	575	51.4	0.097	0.035
Initial BCS[a]	2.77	2.89	2.68	0.78	0.930	0.944
Minimal BCS	1.80	1.91	1.77	0.47	0.704	0.817
Days to minimal BCS[b]	52.0	65.6	66.7	28.9	0.336	0.143
BCS 90 d postpartum	2.45	2.16	2.00	0.63	0.183	0.086

[a] BW and BCS 2 d postpartum.
[b] Last day on which minimal BW or BCS was recorded.
[c] See footnote d in Table 1.

Table 5
Least-square means of ammonia N in ruminal fluid, urea N in plasma, total VFAs in ruminal fluid, and the relative concentration of the individual VFAs

	Diet[1]			S.E.M.	$P>F$
	1	2	3		
NH_3 N (mg/100 ml)	14.0[ab]	12.7[b]	14.7[a]	0.48	0.04
Urea N (mg/100 ml)	20.3	21.2	21.3	0.61	0.53
Total VFAs (mM)	82.5	77.1	82.1	4.3	0.65
Individual VFAs (%):					
Acetate (A)	59.8	58.5	60.4	1.2	0.48
Propionate (P)	26.3	28.0	26.4	0.9	0.42
Butyrate	10.9	10.6	10.8	0.8	0.86
A:P	2.27	2.09	2.29	0.15	0.35

[1] See footnote d in Table 1.
a,b: Means within a row without a common superscript differ according to P value given.

were 14.0, 12.7 and 14.7 mg/100 ml for control cows and cows fed diets 2 and 3, respectively ($P<0.04$; Table 5). Mean plasma urea N concentrations were 20.3, 21.2 and 21.3 mg/100 ml for control cows and cows fed diets 2 and 3, respectively ($P<0.53$; Table 5).

Total mean VFA concentrations in ruminal fluid were 82.5, 77.1 and 82.1 mM/l for control cows and cows fed diets 2 and 3, respectively ($P<0.65$; Table 5). No significant difference was detected among diets for the individual VFA concentrations (percentage of total) during the time before the morning meal was offered and 8 h later (Table 5).

No difference in mean plasma glucose concentrations could be detected among diets (Table 6). The standard deviation and coefficient of variation of

Table 6
Effect of diet on plasma glucose and insulin concentrations

	Diet[3]						$P>F$	Contrast 2 + 3 vs. 1
	1		2		3			
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD		
Glucose[1] (mg/100 ml)	54.1	4.5	54.5	6.8	55.0	6.1	0.943	0.880
CV (%)	8.4[b]		13.0[a]		11.2[a]		0.062	0.041
Insulin[2] (mU/l):								
Week 1	6.55	1.16	5.54	1.05	5.93	0.96	0.540	0.218
Week 7	9.71	1.62	10.55	1.81	10.34	1.67	0.712	0.410

a,b: Means within a row without a common superscript differ according to P value given.
[1] Mean of 30 samples taken from each of seven cows per treatment during experimental period.
[2] Mean of five samples taken from each of 14 cows per treatment during weeks one and seven postpartum.
[3] See footnote d in Table 1.

Table 7
Effect of diet on reproductive performance

	Diet[a]			S.E.M.	$P > F$
	1	2	3		
No. of cows	14	14	14		
Retained placenta	4	2	1		
Metritis	1	7	6		
Days to first ovulation	36.6	36.3	35.4	17.01	0.980
Days to first AI	79.4	70.9	80.4	15.06	0.203
Days open	122.8	117.2	110.4	46.7	0.839
AI per conception	2.3	2.5	2.3	1.31	0.663
Conception rate (%):					
First AI	28.6 (14)[b]	21.4 (14)	28.6 (14)		
Second and third AI	30.8 (13)	25.0 (16)	33.3 (12)		

[a] See footnote d in Table 1.
[b] In parentheses, total number of AI.

plasma glucose concentration for control cows were smaller ($P < 0.103$ and $P < 0.062$, respectively), than those for cows fed diets 2 and 3. Plasma insulin concentrations increased from the first to the seventh week postpartum ($P < 0.001$; Table 6), but there was no significant difference among diets.

The reproductive performance of the experimental cows is presented in Table 7. One cow of each diet was removed before being diagnosed as pregnant. On each diet, 10 of the cows became pregnant. No significant differences among diets could be detected for any of the reproduction parameters except for metritis, which was detected in one control cow but in seven cows fed diet 2 and in six cows fed diet 3.

4. Discussion

4.1. Dry matter intake

Mean DMI of cows fed diets 2 and 3 was lower by 2.4 and 3.4 kg/d, respectively, than that of the control cows (Table 3). Differences in DMI among treatments could not be analyzed statistically because the cows were fed as a group. However, since CGM is used in large quantities in dairy cow rations, and other performance parameters like as BW and BCS, were significantly affected by CGM supplementation, it was assumed that this issue should be addressed.

The reduced DMI might be attributed to the CGM component of diets 2 and 3 because other ingredients were fed nearly in similar amounts in all diets. Soybean meal and rapeseed meal were supplemented to all diets at similar concentrations (Table 1) and changes in dietary UDCP were achieved by the addition of 25 g/kg of CGM. Dietary UDCP in both diets was increased by 1.1%, which in diet 2 was on the account of the dietary RDCP, but not in diet 3. Dietary RDCP in diet 3 was the same as that in the control diet, but dietary CP concentration was increased by 1.3%. Accordingly, a shortage of RDCP that was required for optimal fermentation by ruminal microbes could not explain the reduced DMI of cows fed diets 2 and 3. More likely, factors related to CGM in these diets were responsible for the negative effect on DMI. Most feedstuffs that are high in UDCP are of animal source. Reduced intake of diets supplemented with fish meal (Bruckental et al., 1989; Wholt et al., 1991; Atwall and Erfle, 1992), meat and bone meal (Mabjeesh et al., 1996), and blood meal and feather meal (Waltz et al., 1989) were attributed to palatability or high fat contents. Reduced DMI as a result of feeding CGM was reported for cows (Fleck et al., 1988; Blauwiekel et al., 1990; Wholt et al., 1991; Wheeler et al., 1995) and lambs (Staples et al., 1990). However, others (Holter et al., 1992; Cozzi and Polan, 1994) reported no effect of CGM on DMI. Reviewing the 12-year literature of RUDCP in dairy cows diets, Santos et al., (1998) concluded that supplementation of CGM resulted in mostly negative results. However, no consistent effect and no definite explanation on dietary composition basis could be shown.

The similarity in the response of cows on diets 2 and 3 to supplemental CGM in DMI, BW loss and BCS change proves the sensitivity of high-yielding cows a short time after calving to dietary CGM. According to Wheeler et al. (1995), dietary RUDCP level is responsible for increasing insulin concentrations of cows in early lactation. This period is characterized by low DMI and high milk production, which is maintained by extensive lipolysis of fatty tissues and gluconeogenesis. Blood insulin concentration is very low immediately after calving (Koprowski and Tucker, 1973; Hart et al., 1978; Blauwiekel et al., 1990), which enables a gradual increase in DMI. The CPS treatment (combination protein supplement) in Wheeler et al. (1995) experiment, included CGM without soybean meal (SBM), and was most effective in increasing blood insulin level. Similar results were reported by Landau et al. (1996), as insulin level was increased in the blood of CGM-fed ewes but not in SBM-fed ewes. In the present trial, plasma insulin concentrations increased during seven weeks postpartum ($P < 0.001$; Table 6). However, no significant difference between control cows and cows fed diets 2 and 3 could be found, except that the increase in insulin tended to be faster for diets 2 and 3 (an increase of 3.16, 5.01 and 4.41 mU/l per seven weeks, on diets 1, 2 and 3, respectively). The decrease in feed intake by cows fed diets 2 and 3 and the probable leveling down CGM intake, apparently avoided the extra excretion of insulin. Greater fluctuations in the plasma glucose concentration of cows fed diets 2 and 3, as compared with those of control cows (Table 6), may also point to a non-stable glucose metabolism. Later in lactation, when peak feed intake is reached, blood insulin concentrations are much higher, and dietary CGM might not have the same impact on metabolism. This may explain contradictory reports on the effect of dietary CGM on DMI by milking cows.

4.2. Body weight and milk yield

Postpartum loss of BW was significantly greater for cows fed diets 2 and 3 than for control cows (Table 4 and Fig. 1b). However, no differences were found in milk yield (Table 3 and Fig. 1a) or milk composition among diets. Similar results were reported by Wholt et al. (1991), as CGM-supplemented cows lost 58 kg BW during 14 to 16 weeks of lactation. Cows fed fish meal lost 30 kg during four weeks and cows fed SBM lost 37 kg during 10 weeks (Wholt et al., 1991). Differences in mean DMI between cows fed the control diet and cows fed diets 2 and 3 during 45 d of BW loss were 2.4 and 3.4 kg/d, respectively, which are equivalent to 186 and 263 Mcal NE_l per 45 d, respectively. These results correlate well with the energy equivalent of 270 Mcal for 55 kg BW loss (NRC, 1989) of the CGM fed cows. However, the gradual increase in postcalving DMI masks the actual BW loss, which might be even greater. Days to minimal body condition (BC) may better represent the period of a negative energy balance. Days to minimal BC score (BCS) were greater than days to minimal BW by 25, 21 and 22 d for control cows and cows fed diets 2 and 3, respectively (Table 4). Likewise, the rates of increase in BCS after minimal value was reached up to the end of the experiment, were 0.0171, 0.0102 and 0.0099 BCS units per day for the control cows and cows on diets 2 and 3, respectively. This emphasizes the metabolic difficulty of the CGM-fed cow to recover and shift to a positive energy balance later in lactation.

These results are not compatible with our expectations for a better energy balance by cows fed the diets supplemented with UDCP (Garnsworthy and Cole, 1990; Dhiman and Satter, 1993; Bruckental et al., 1996). It seems that the effect on DMI, BW loss and BCS of cows on diets 2 and 3, during the first period postpartum, cannot be attributed to the higher undegradability of dietary CP but to a more specific effect of CGM.

4.3. Reproductive performance

Dairy cows cannot maintain a positive dietary energy balance early in lactation. A correlation was shown between energy balance at the beginning of lactation and fertility (Andersson et al., 1991). According to Butler and Smith (1989), negative energy balance probably acts similarly to undernutrition and may be manifested in delayed ovarian activity and reduced fertility. In the present study, the protocol for reproductive management included an extensive follow-up of cows from calving throughout the experiment. Although significant differences among diets were demonstrated for mean BW loss and for BCS, experimental effects on reproduction were not detected (Table 7). Similar results were reported by Bar-Peled et al. (1995), when BW loss and reduced BCS were much greater for suckled cows than for the control and for cows milked six times daily. However, fertility of the suckled cows was similar to the cows on the two other treatments (personal communication). Fertility of ewes fed with CGM for four days before and four days after treatment with prostaglandin $F_{2\alpha}$, was better than that of ewes fed SBM or isoenergetic supplement (Landau et al., 1996). They concluded that insulin and glucose metabolism may be involved in the effect of supplemental protein. Likewise, a better fertility has been reported for cows fed low as compared with high CP degradable diets (Ferguson et al., 1988; Bruckental et al., 1989; Canfield et al., 1990; Ferguson et al., 1993). The incidence of retained placenta is affected mainly by the condition of the cow before and during calving, and no treatment effect was expected. Appearance of metritis is induced by the postpartum physiological condition of the cow. The higher incidence of metritis in cows fed diets 2 and 3 compared with control cows (Table 7) could have been a result of a greater negative balance of energy and of other nutrients, which could increase the sensitivity of genital organs to pathogens. However, because of good management, including early detection of disorders, timely treatment and subsequent monitoring for the efficacy of a treatment, no effect on days to first ovulation or days to first AI could be detected (Table 7). Howard et al. (1987) and Barton et al. (1996) claimed that many declines in reproduction attributed to nutritional factors could be controlled by a proper veterinary management.

5. Conclusions

DMI of dairy cows during the first period after calving is low and cannot fulfill energy requirements for production. Feeding the cows diets containing approximately 40 g/kg CGM might reduce DMI and increase their negative energy balance. Reduced DMI may be a result of the effect of dietary CGM on blood insulin level during early lactation.

Acknowledgements

The authors thank Channa Lehrer and Moshe Nikbachat for technical assistance.

References

Arieli, A., Bruckental, I., Smoler, E., 1989. Prediction of duodenal nitrogen supply from degradation of organic and nitrogenous matter in-situ. J. Dairy Sci. 72, 2532–2539.

Andersson, L., Gustafsson, A.H., Emanuelson, U., 1991. Effect of hyperketonaemia and feeding on fertility in dairy cows. Theriogenology 36, 521.

Atwall, A.S., Erfle, J.D., 1992. Effects of feeding fishmeal to cows on digestibility, milk production and milk composition. J. Dairy Sci. 75, 502–507.

Bar-Peled, U., Maltz, E., Bruckental, I., Folman, Y., Kali, Y., Gacitua, H., Lehrer, R., Knight, C.H., Robinzon, B., Voet, H., Tagari, H., 1995. Relationship between frequent milking or suckling in early lactation and milk production of high producing dairy cows. J. Dairy Sci. 78, 2726–2736.

Barton, B.A., Rosario, H.A., Anderson, G.W., Grindle, B.P., Carroll, D.J., 1996. Effects of dietary crude protein, breed, parity and health status on the fertility of dairy cows. J. Dairy Sci. 79, 2225–2236.

Blauwiekel, R., Hoover, W.H., Slider, S.D., Miller, T.K., 1990. Effects of fish meal protein supplementation on milk yield and composition and blood constituents of dairy cows. J. Dairy Sci. 73, 3217–3221.

Bruckental, I., Drori, D., Kaim, M., Lehrer, H., Folman, Y., 1989. Effect of source and level of protein on milk yield and reproductive performance of high-producing primiparous and multiparous dairy cows. Anim. Prod. 48, 319–329.

Bruckental, I., Tagari, H., Arieli, A., Zamwell, S., Aharoni, Y., Genizi, A., 1996. The effect of undegradable crude protein supplementation on milk production and composition and reproduction of early lactating cows. J. Anim. feed Sci. 5, 95–106.

Butler, W.R., Smith, R.D., 1989. Interrelationships between energy balance and postpartum reproductive function in dairy cattle. J. Dairy Sci. 72, 767–783.

Canfield, R.W., Sniffen, C.J., Butler, W.R., 1990. Effect of excess degradable protein on postpartum reproduction and energy balance in dairy cattle. J. Dairy Sci. 73, 2342–2349.

Carroll, D.J., Jerred, M.J., Grummer, M.J., Combs, D.K., Pierson, R.A., Hauser, E.R., 1990. Effect of fat supplementation and immature alfalfa to concentrate ratio on plasma progesterone, energy balance and reproductive traits of dairy cattle. J. Dairy Sci. 73, 2855–2863.

Cozzi, G., Polan, C.E., 1994. Corn gluten meal or dried brewers grain as partial replacement for soybean meal in the diet of Holstein cows. J. Dairy Sci. 77, 825–834.

Dhiman, T.R., Satter, L.D., 1993. Protein as the first limiting nutrient for lactating dairy cows fed high proportions of good quality alfalfa silage. J. Dairy Sci. 76, 1960–1971.

Ferguson, J.D., Blanchard, T., Galligan, D.T., Hoshall, D.C., Chalupa, W., 1988. Infertility in dairy cattle fed a high percentage of protein degradable in the rumen. J. Am. Vet. Med. Assoc. 192, 659–662.

Ferguson, J.D., Callgan, D.T., Blanchard, T., Reeves, M., 1993. Serum urea nitrogen and conception rate: the usefulness of test information. J. Dairy Sci. 76, 3742–3746.

Fleck, A.T., Lusby, K.S., Owens, F.N., McCollum, F.T., 1988. Effects of corn gluten feed on forage intake, digestibility and ruminal parameters of cattle fed native grass hay. J. Anim. Sci. 66, 750–757.

Garnsworthy, P.C., Cole, D.J.A., 1990. The importance of intake in feed evaluation. In: Wiesman, J., Cole, D.J.A. (Eds.), Feedstuff Evaluation, Butterworths, London, p. 147.

Hart, I.C., Bines, J.A., Morant, S.V., Ridley, J.L., 1978. Endocrine control of energy metabolism in the cow: comparison of the levels of hormones (prolactin, growth hormone, insulin and thyroxine) and metabolites in the plasma of high- and low-yielding cattle at various stages of lactation. J. Endocrinol. 77, 333.

Holter, J.B., Hayes, H.H., Urban, Jr. W.E., Ramsey, S., Ridequt, H., 1992. Response of Holstein cows to corn gluten meal used to increase undegradable protein in early or later lactation. J. Dairy Sci. 75, 1495–1506.

Howard, H.J., Aalseth, E.P., Adams, G.D., Bish, L.J., McNew, R.W., Dawson, L.J., 1987. Influence of dietary protein on reproductive performance of dairy cows. J. Dairy Sci. 70, 1563–1571.

Koprowski, J.A., Tucker, H.A., 1973. Bovine serum growth hormone, corticoids and insulin during lactation. Endocrinology 93, 645–651.

Lamming, G.E., 1998. Alternatives to invasive genetic engineering in animal production. In: Garnsworthy, P.C., Wiseman, J. (Eds.), Recent Advances in Animal Nutrition, University Press, Nottingham, pp. 153–163.

Landau, S., Houghton, J.A.S., Mawhinney, J.R., Inskeep, E.K., 1996. Protein sources affect follicular dynamics in ewes near the onset of the breeding season. Reprod. Fertil. Dev. 8, 1021–1028.

Mabjeesh, S.J., Arieli, A., Bruckental, I., Zamwell, S., Tagari, H., 1996. Effect of type of protein supplementation on duodenal amino acid flow and absorption in lactating dairy cows. J. Dairy Sci. 79, 1792–1801.

Nebel, R.L., McGillard, M.L., 1993. Interactions of high milk and reproductive performance in dairy cows. J. Dairy Sci. 76, 3257–3268.

NRC, 1989. Nutrient Requirements of Dairy Cattle, National Research Council, National Academy Press, Washington, DC.

Ørskov, E.R., McDonald, I., 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to the rate of passage. J. Agric. Sci. (Camb.) 92, 499–504.

Ostergaard, V., Korver, S., Solbu, H., Anderson, B.B., Oldham, J., Wiktorsson, H., 1990. Main report – E.A.A.P working group on: efficiency in the dairy cow. Livest. Prod. Sci. 24, 287–304.

Ron, M., Bar-Anan, R., Wiggans, G.R., 1984. Factors affecting conception rate of Israeli Holstein cattle. J. Dairy Sci. 67, 854–864.

Santos, F.A.P., Santos, J.E.P., Theurer, C.B., Huber, T., 1998. Effects of rumen-undegradable protein on dairy cow performance: a 12-year literature review. J. Dairy Sci. 81, 3182–3213.

SAS, 1985. SAS User's Guide: Statistics, Version 5 ed., SAS Institute, Cary, NC.

Sklan, D., Moalem, U., Folman, Y., 1991. Effect of feeding calcium soaps of fatty acids on production and reproduction responses in high producing lactating cows. J. Dairy Sci. 74, 510–517.

Spicer, L.J., Vernon, R.K., Tucker, W.B., Wattermann, R.P., Hogue, J.F., Adams, G.D., 1993. Effect of inert fat on energy balance, plasma concentrations of hormones, and reproduction in dairy cattle. J. Dairy Sci. 76, 2664–2673.

Staples, C.R., Thatcher, W.W., Clark, J.H., 1990. Relationship between ovarian activity and energy status during the early postpartum period of high producing dairy cows. J. Dairy Sci. 73, 938–947.

Tagari, H., 1969. Comparison of the efficiency of protein contained in lucerne hay and soya-bean meal for sheep. Br. J. Nutr. 23, 455–470.

Tyrrel, H.F., Reid, J.T., 1965. Prediction of the energy value of cow's milk. J. Dairy Sci. 48, 1215–1223.

Van Soest, P.J., Robertson, J.B., Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74, 3583–3597.

Waltz, D.M., Stern, M.D., Illg, D.J., 1989. Effect of ruminal protein degradation of blood meal and feather meal on the intestinal amino acid supply to lactating cows. J. Dairy Sci. 72, 1509–1518.

Wheeler, J.G., Amos, H.E., Froetschel, M.A., Coomer, J.C., Maddox, T., 1995. Responses of early lactation cows fed winter and summer annual forages and undegradable intake protein. J. Dairy Sci. 78, 2767–2781.

Wholt, J.E., Chmiel, S.L., Zajac, P.K., Backer, L., Blethen, D.B., Evans, J.L., 1991. Dry matter intake, milk yield and composition and nitrogen use in Holstein cows fed soybeans, fish or corn gluten meals. J. Dairy Sci. 74, 1609–1622.