Session N4. 46, Abstract no. 333

EFFECT OF ENERGY AND PROTEIN FEEDING LEVELS IN PRE- AND POSTPUBERTAL BLACK-AND-WHITE x HOLSTEIN-FRIESIAN CROSSBREED HEIFERS ON PRODUCTIVE TRAITS AND MILK YIELD

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ABSTRACT

The studies were carried out with 43 Black-and-White heifers (77.5% HF) from 6 months of age to 100 days of lactation. Animals were assigned to 5 groups equivalent in terms of genotype, age and body weight (8-10 animals per group). From 6 to 11 months of age (period 1) and from 12 to 13 months of age (period 2), they were fed diets with different energy (UFL) and protein (PDI) levels according to IZ-INRA requirements (2001). From 14 months of age to 3 weeks before calving, all the heifers were fed the same diets as in group K. Thereafter heifers were fed with rations formulated for dairy cows, assuming the maximum production (MP) at peak lactation to be 30 kg milk per day. In each age group and prior to and after calving, highly significant relationships were found between body condition score (BCS) on a 5-point scale and subcutaneous fat thickness (SFT) on the back. Increasing the energy (UFL) and protein (PDI) level in the diet to 115% of the IZ-INRA requirement (2001), formulated for a daily gain of 700 g in prepubertal (period 1) and postpubertal (period 2) heifers, improved body condition, increased body fatness within the range considered optimal for this breed, and helped to obtain heavier and taller animals after puberty. This way of feeding the heifers had no adverse effect on reproductive parameters, but reduced age at first calving and had a favourable effect on dairy performance of first-calving cows over the first 100 days of lactation.

KEY WORDS: heifers, Black-and-White breed, reproductive performance, dairy performance, feeding

INTRODUCTION

Increased plane of nutrition and thus daily gains of heifers may be applied to reduce the age of sexual maturity, which is related to body weight (Sejrsen and Purup, 1997). However, oversupply of energy accompanied by deficient protein in a prepubertal diet may weaken the growth of the mammary gland (Radcliff et al., 1997; Silva et al., 2002) and lead to excess fatness, decreased growth performance, and subsequent poorer milk yield of the heifers (Abeni et al., 2000). The majority of high-producing cows in Poland are Black-and-White (BW) with high percentage of Holstein-Friesian (HF) breeding. There is a shortage of data on the effects of energy and protein feeding level of prepubertal and postpubertal BW × HF heifers crossbreed on growth, body condition, fatness, and reproductive and dairy performance.

The objective of this study was to determine the effect of feeding prepubertal and postpubertal rations differing in energy and protein levels on growth, condition, fatness, and reproductive and dairy performance of Black-and-White heifers with a high percentage of Holstein-Friesian genes (range 60.1-92.1%, 77.5% on average) and to estimate the relationship between body condition score and degree of fatness as measured on live animals by subcutaneous fat thickness on the back.

MATERIAL AND METHODS

A total of 43 Black-and-White heifers with a high (77.5% on average; range from 60.1 to 92.1%) percentage of Holstein-Friesian genes were studied from 6 months of age to 100 days of lactation. Animals were assigned to 5 groups equivalent in terms of genotype, age and

body weight (8-10 animals per group). From 6 to 11 months (period 1) and from 12 to 13 months of age (period 2) they were fed rations with different energy (UFL) and protein (PDI) levels according to IZ-INRA requirements (2001). In the control group (K), in conformation with these recommendations, the rations met 100% of the requirement for UFL and PDI and were formulated to achieve daily gains of 700 g. In the other groups compared to group K, UFL and PDI levels in period 1 and 2 were (%): 85/85 and 115/115 (group A); 85/115 and 100/100 (group B); 115/85 and 100/100 (group C); 115/115 and 115/115 (group D). During the period from 14 months of age to 3 weeks before calving, all the heifers received a ration formulated to achieve a daily gain of 700 g. Thereafter heifers were fed rations formulated for first-calving cows, assuming the maximum production (MP) at peak lactation to be 30 kg milk per day.

Basic chemical composition of the feeds was determined according to standard procedures (AOAC, 1990). Volatile fatty acids (VFA) in silages were determined with gas chromatography, and lactic acid with high-performance liquid chromatography (HPLC). The pH value of silage was determined with the Elwsko N517 potentiometer.

Body weights, dimensions and body condition score (BCS) on a 5-point scale during the growth of heifers from 6 to 18 months of age were determined at monthly intervals, and then 7 days before predicted calving date and at 7, 35 and 100 days of lactation. Body condition was estimated independently by 2 or 3 testers according to Wildman et al. (1982), and the final result was an average of different evaluations.

At 6, 11, 13 and 18 months of age, on day 7 before calving and on day 35 after calving, all animals were ultrasound measured to determine subcutaneous fat thickness (SFT) on the back, at the last thoracic vertebra. Measurements were made with an Aloka model SSD-500 (Aloka Co. Ltd., Japan), equipped with a 3.5 MHz, 12 cm linear-array transducer.

Reproductive performance of the heifers was determined from the insemination index, conception rate and age and body weight at first oestrus, at conception and at calving. The course of calving was classified according to 3 types: spontaneous (unassisted), intermediate (requiring moderate assistance), and difficult (requiring assistance from a veterinary doctor) (Choi et al., 1997).

Cows were milked twice daily. Milk output from each cow was measured daily using TRU-TEST milk meters, and milk composition was determined at weekly intervals using Milko-Scan FT 120 Foss Electric.

Energy and protein value of the feeds and feed ingredients of the ration were formulated based on IZ-INRA requirements (2001) using WINWAR software ver. 1.6 (2000) and INRAtion ver. 2.63 (1998).

Statistical calculations were made with one-way analysis of variance using the GLM procedure of SAS (1989). Correlation coefficients between BCS (1-5 points) and subcutaneous fat thickness (SFT) were calculated using the CORR procedure of SAS.

The values designated in tables with different letters differ significantly, capital letters indicating highly significant differences ($P \leq 0.01$), small letters – significant differences ($P \leq 0.05$), no letters – non-significant differences ($P > 0.05$).

RESULTS

Heifers fed from 6 to 11 months of age on rations with higher energy (group C) or energy and protein (group D) levels than in the control group (K) achieved higher ($P \leq 0.01$) daily weight gains during that period and greater ($P \leq 0.01$ or $P \leq 0.05$) body weights at 11, 13 and 18 months of age than animals from the groups K, A and B (Table 1). No statistically significant differences were also shown for body weight and condition of animals as measured 7 days before calving.

Table 1. Body measurements, body weight, daily weight gains, body condition score and subcutaneous fat thickness

Item	Groups					RMSE
	K	A	B	C	D	
Height at withers (cm) at months of age:						
11	113.7AB	111.1A	113.2AB	113.9AB	115.8B	2.75
13	118.0	117.6A	118.1	118.2	119.4	2.81
18	128.1	127.9	127.6	128.3	129.6	2.77
before calving [1]	136.1	136.7	136.7	136.1	137.6	2.05
after calving (100 day)	138.0	138.6	138.0	137.3	139.4	2.13
Body weight (kg) at months of age:						
6	173.1	171.6	177.6	168.9	168.1	22.68
11	271.5ABa	248.3Aa	255.1Aa	293.0Bb	296.4Bb	24.67
13	315.0ab	303.4a	299.7a	336.6bc	349.5c	25.38
18	429.0ab	424.8ab	410.3a	446.4bc	457.9c	27.33
before calving	596.0	624.3	602.0	625.0	628.7	35.62
after calving (day):						
7	559.4	569.0	549.0	573.6	574.3	33.05
35	532.0	540.9	521.1	537.2	538.9	30.35
100	549.9	564.6	547.6	563.9	568.6	33.33
Daily weight gain (g/day) at months of age:						
6 - 11	648.0A	505.1B	509.7B	816.1C	843.7C	49.30
12 - 13	714.6A	910.1B	733.4A	714.4A	871.5B	76.74
14 - 18	710.7ab	750.6b	690.7ab	705.6ab	668.5ac	74.75
19 - calving [1]	713.5	714.3	715.7	688.7	726.0	61.07
Body condition score (BCS pts) at at months of age:						
6	2.17	2.15	2.18	2.19	2.20	0.16
11	2.77B	2.50C	2.53B	2.98A	2.95A	0.14
13	2.89ABb	2.88ABb	2.78Bb	3.04Aa	3.03Aa	0.14
18	2.99ab	2.96a	2.89Bc	3.08Aa	3.05Aab	0.11
before calving [1]	3.41	3.40	3.40	3.51	3.54	0.24
after calving (day);						
7	2.88	2.76	2.88	2.90	2.90	0.15
13	2.69	2.63	2.67	2.71	2.71	0.13
100	2.94	2.89	2.87	2.96	2.96	0.11
Subcutaneous fat thickness (SFT mm) at months of age:						
6	2.87	2.92	3.10	3.04	3.11	0.45
11	4.49Bb	3.95Bc	4.16Bbc	5.61Aa	5.29Aa	0.45
13	4.98ABbc	5.03ABbc	4.92Bc	5.89Aa	5.63ABab	0.63
18	5.50ABbc	5.31Bc	5.21Bc	5.96Aa	5.84Aab	0.36
before calving [1]	8.07	8,19	8.01	8.07	8.08	0.49
after calving (35day)	5.90	6.45	6.20	6.10	5.76	0.16

[1] 7 day

RMSE = $\sqrt{S^2}$

At 11, 13 and 18 months of age and on day 7 before calving, heifers in group D were characterized by greater height at withers than animals in the other groups, although the differences were significant ($P \leq 0.01$) only in comparison with group A at 11 months of age. Compared to heifers from groups A, B and K, animals from group D were also characterized by higher ($P \leq 0.01$, $P \leq 0.05$ or $P > 0.05$) body condition scores at 11, 13 and 18 months of age

and greater fatness at that age. Values of body condition and fatness increased successively from 6 months of age to calving, irrespective of the plane of nutrition applied in the first period of experiment.

Between first-calving cows from different groups, there were no significant differences ($P>0.05$) in body weight and condition, as measured 7, 35 and 100 days postcalving. No statistically significant differences were also found, in height at withers on day 100 of lactation, and in subcutaneous fat thickness on the back on day 35 of lactation.

Heifers from group D calved approximately 27 days earlier than those from groups C and K and 40 days earlier than those from groups A and B (Table 2). Animals from group D were also significantly younger ($P\leq0.01$) at first oestrus and significantly younger ($P\leq0.05$) at conception than those in group A. No significant differences ($P>0.05$) were found between the groups in body weight at first oestrus, at conception and at calving, in the conception rate and in the insemination index. In most cases (87.8%) calvings required moderate assistance or were spontaneous. Dystocia that required assistance from a veterinary doctor was also observed in single animals from groups K, A and D and in two heifers from group C.

Cows from group D produced over the first 100 days of lactation approximately 8% more milk than their contemporaries from groups K and B and approximately 6% more milk than animals from groups A and C (Table 2). They also achieved higher yields of fat, protein and lactose, greater percentage of casein, lactose and solids, and showed a maximum daily milk production at peak lactation that was higher than in the other groups. Between groups there were no statistically significant differences in the urea content of milk, which averaged 184.7 mg/l.

Table 2. Reproductive performance and milk yield of primiparous cows

Ithem	Groups					RMSE [1]
	K	A	B	C	D	
Fertilization index (%)	62.5	50.0	50.0	50.0	55.0	
Insemination index	1.35	1.43	1.50	1.50	1.44	0.39
Age (months):						
at first oestrus	10.80A	10.90A	10.09A	9.71B	9.61B	0.84
at conception	17.85ab	18.33a	17.84ab	17.16ab	16.46b	1.46
at calving	26.6	27.2	27.0	26.2	25.5	1.43
Body weight (kg):						
at first oestrus	258.2	254.8	255.0	265.2	268.9	15.20
at conception	412.3	419.4	411.4	426.9	420.8	29.43
at calving [2]	596.0	624.3	602.0	625.0	628.7	35.62
Course of calving:						
spontaneous	3	3	4	2	4	
intermediate	4	4	4	4	4	
difficult	1	1	0	2	1	
Milk yield (total), kg	2577.3	2615.3	2568.7	2616.8	2779.4	298.6
Fat, %	4.05	4.17	4.14	4.16	4.23	0.181
Protein ,%	3.25	3.21	3.12	3.22	3.22	1.160
Lactose, %	4.90	4.89	4.92	4.87	4.96	0.086
Casein, %	2.68	2.67	2.63	2.69	2.73	0.141
Dry matter, %	12.26	12.23	12.35	12.69	12.82	0.511
Urea (mg/l)	209.6	184.3	164.6	172.0	206.5	58.64
Peak milk production (PM), kg/day	28.7	28.8	29.3	29.5	30.4	3.65

[1] see Table 1, [2] 7 day

In each age class, prior to calving and after calving highly significant correlation coefficients were shown between body condition score (BCS) and subcutaneous fat thickness (SFT) on the back (Table 3).

Table 3. Relationship between body condition score (BCS) and subcutaneous fat thickness (SFT) on the back in the heifers of different age, before calving and after calving

Age (months) and lactation period (days)	Body condition score (BCS, pts)	Regression equations (Y= a + bx)	Correlation coefficient-R	Level of statistical significance-P
6	2.18	SFT = - 5.501 + 3.906 8 BCS	0.950	0.0001
11	2.76	SFT = - 3.827 + 3.108 * BCS	0.970	0.0001
13	2.93	SFT = - 6.139 + 3.904 * BCS	0.908	0.0001
18	3.00	SFT = - 5.386 + 3.661 * BCS	0.937	0.0001
Before calving (day 7)	3.46	SFT = 3.240 + 1.400 * BCS	0.742	0.0001
After calving (day 35)	2.72	SFT = 1.554 + 1.675 * BCS	0.429	0.0009

DISCUSSION

The parameters of growth and body condition obtained during the experiment in groups K, C and D are close to the recommended standards for Holstein-Friesian heifers fed semi-intensively (Hoffman, 1997). Similar results for body condition score of prepubertal Holstein-Friesian heifers fed rations with about 15% increased net energy and crude protein levels in relation to NRC requirements (1989) for daily gain of 700 g before puberty were reported by many authors in their studies with HF heifers (Abeni et al., 2000; Pirlo et al., 1997; Van Amburgh et al., 1998). The higher level of energy and protein used in heifers from group D in period 1 and 2 of the experiment, which was decreased between 14 months of age and 3 weeks prior to calving, than the requirement determined for the control group (K), did not cause, compared to that group, a significant increase in body condition score and subcutaneous fat thickness on the back at 18 months of age and before calving. It is therefore suggested that increasing prepubertal and postpubertal levels of energy and protein in the rations to 115% of the IZ-INRA requirements (2001) determined for daily weight gains of 700 g, does not cause BW × HF heifers to become excessively fat at 18 months of age and prior to calving. It is possible that increasing the energy and protein level in the ration to achieve higher daily weight gains in the prepubertal period may exert varying effects on deposition of subcutaneous fat in heifers depending on age (Abeni et al., 2000). Some studies with HF heifers showed that excess energy and deficient protein in the ration fed at that time led to poorer growth performance (Radcliff et al., 1997), excess fatness of animals and of the mammary gland (Dobos et al., 2000; Silva et al., 2002) and delayed subsequent milk performance (Abeni et al., 2000). This was confirmed to a certain degree by the present work in group C heifers, which were fed in period 1 with rations higher in energy and lower in protein.

The analysis of growth performance of the heifers based on their height at withers showed that elevating energy and protein in the ration to 115% (group D) of the IZ-INRA requirement for a daily gain of 700 g in the prepubertal and postpubertal period did not significantly change the ratio between height at withers and body weight, but resulted in

animals that were heavier and had greater height at withers. Also other studies (Pirlo et al., 1997), carried out with HF heifers fed according to NRC requirements (1989), demonstrated that when rations were well balanced for energy and protein, the high level of feeding in the pubertal period did not alter the ratio between height at withers and body weight compared to standard nutrition. As a result of such feeding, heavier heifers with greater height at withers and earlier dates of conception and calving were obtained (Bilik et al., 2001; Peri et al., 1993).

The higher scores for condition shown in the present study for heifers fed intensively with regard to energy or energy and protein than for heifers on a lower plane of nutrition, resulted from their greater fatness. This was confirmed by the high correlation coefficients estimated between these traits. Considering the high relationship between body condition scores and subcutaneous fat thickness on the back in different periods of growth, it may be assumed that accurate estimation of body condition on a 5-point scale of BCS may be sufficient for determining the degree of fatness in Black-and-White heifers with a high percentage of HF genes.

Reproductive indicators in heifers fed from 6 to 13 months of age with rations higher in energy and protein (group D) indicate the possibility of advancing the reproductive period (by about 5 weeks) and thus of decreasing the age at first calving, compared to animals fed on a lower plane of energy and protein nutrition. Similar results were also shown by other authors (Hinders, 1997; Sejrsen and Purup, 1997) in experiments with dairy heifers. The feeding levels used in the current study for heifers from 6 to 13 months of age also had no effect on the course of calving, which was mostly spontaneous or required moderate assistance.

Slightly better production results obtained in group D than in the other groups suggest that the higher level of energy and protein feeding than recommended by IZ-INRA requirements during the pubertal period may be recommended for growth of BW heifers. Only heifers subjected to this feeding system in the pubertal period achieved the expected milk production at peak lactation and showed a tendency for higher total milk production.. Other authors (Hinders, 1997; Pirlo et al., 1997) also showed that accelerated growth of prepubertal HF heifers, as a result of feeding high-energy and high-protein rations, did not decrease their future milk production compared to heifers fed with standard rations according to NRC (1989). The present results and those of other authors reported herein may suggest that modern Holstein-Friesian or Black-and-White heifers with a high percentage of HF breeding tolerate higher levels of energy and protein feeding in the pubertal period, without negative implications for their subsequent reproductive and milk performnce.

CONCLUSION

- That regular BCS assessment on a 5-point scale and periodical ultrasound measurements of subcutaneous fat thickness on the back during the growth of dairy heifers, make it possible to control the growth process.
- Increasing the pre- and postpubertal levels (6 to 13 months of age) of energy (UFL) and protein (PDI) in rations to 115% of the IZ-INRA recommendations (2001) formulated for a daily gain of 700 g, increased frame size, body condition and body fatness within the limits regarded as optimal for Black-and-White heifers with a high (60-90%) percentage of HF genes.
- The growth of pre- and postpubertal heifers, accelerated by means of diets with increased energy and protein levels, does not negatively affect reproductive parameters, but decreases age at first calving and may have a beneficial effect on milk performance of first-calving cows.

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