

EFFECT OF COW NUTRITION IN THE FAR-OFF PERIOD ON COLOSTRUM QUALITY AND IMMUNE RESPONSE OF CALVES

WŁODZIMIERZ NOWAK, ROBERT MIKUŁA, MAŁGORZATA KASPROWICZ-POTOCKA, MARTA IGNATOWICZ, ANDRZEJ ZACHWIEJA¹, KATARZYNA PACZYŃSKA¹, AND EWA PECKA¹

Department of Animal Nutrition and Feed Management,
Poznan University of Life Sciences, 60–637 Poznan, Poland

¹Institute of Animal Breeding,
Wroclaw University of Environmental and Life Science, 51-630 Wroclaw, Poland
nowakwl@jay.au.poznan.pl

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Abstract

The aim of the study was to determine the effect of the limitation of energy intake by restrictive dry matter intake in the far-off part (from -56 d to -22 d) of dry period on the colostrum quality and the calf immunological status. Thirty-eight Polish Holstein-Friesian Black and White multiparous cows and their calves were randomly allotted to one of the two dietary treatments in the far-off period. In group ADLIB, diet was offered *ad libitum* (2.0% body weight), while in group REST, dry matter intake was restricted to 1.5% of body weight. Lowered feed intake in the far-off period did not have a statistically significant influence on the quality of colostrum. On the 3rd d of calves' life, serum concentrations of immunoglobulins, albumins, globulins, total protein, and IGF-1 were not affected by treatments of dam in the far-off period. The concentrations of total Ig and G and A immunoglobulins of 21-day-old calves from cows fed *ad libitum* during the far-off period was found to be significantly lower compared to REST group. No significant differences in birth weight and growth rate during the first 21 d of life were found. Limiting maternal diet in far-off period did not affect negatively colostrum quality and calves' immune response during early stages of their life.

Key words: cow, calves, period far-off, colostrum, immunoglobulins.

The nutritional strategy in the dry period, which is commonly regarded as classical, does not guarantee the correct metabolic status of high-yield dairy cows in the perinatal period. The most doubts arise in connection with the energy value of diets in the far-off and close-up periods and new concepts of nutrition assume that during this period, cows take more energy from the feed than they actually need (1, 7). Limitation of energy intake during the dry period as one of the elements of restrictive feeding may improve cow's metabolic status before calving (prepartum period) and the yield results after calving (postpartum period) (6, 16, 26). Dann *et al.* (4) found that excessive energy intake in the far-off period had a more negative influence on dairy cow metabolism after calving than overfeeding in the close-up period. The relationship between cow nutrition during pregnancy and calf resistance is a separate issue, to which not much attention has been devoted so far (18, 19, 23). Earlier studies showed that nutrient deficiency could have a negative effect on the quality and quantity of the produced colostrum (25). Burton *et al.* (3), in turn, found that lower protein concentration in the feed administered during the dry period did not reduce the concentration of immunoglobulins in the colostrum, but lowered their absorption in the calf digestive system. Difficult births in cows, which result from metabolic

disorders as a consequence of improper nutrition and, in particular, the cows' excessive condition in the dry period, also have a negative influence on calf survival rates (22, 29).

Becoming familiar with the mechanism regulating the relationship between the cow and the calf in the last period of pregnancy would make it possible to devise a new strategy for nutrition of the dry cows and to minimise the occurrence of metabolic disorders in cows in the perinatal period, which would facilitate the proper initiation of lactation without negative effects on calf raising. The aim of the study was to determine the influence of the limitation of energy intake by restrictive limited dry matter intake in the far-off period (from -56 d to -22 d) on the quality of colostrum and the calf immunological status.

Material and Methods

Animal model and design of experiment. All the procedures were approved by the Local Ethical Committee. Thirty-eight Polish Holstein-Friesian multiparous cows and their resulting calves according to the expected parturition were randomly allotted to one of the two dietary treatment groups in the far-off period (from -56 d to -21 d). The diet for the far-off period for

both groups consisted of wheat straw (34.5% DM), maize, dried alfalfa silages, and soybean meal. It was formulated to meet 0.69 UFL in 1 kg DM (53% NDF). The diets were balanced using the INRAtion ver. 3.3 software; feed nutritive values were estimated by the PrevAlim 3.23. In the first treatment (ADLIB group), the diet was offered *ad libitum* (established at 2.0% of body weight – b.w.) while in the second treatment (REST group) dry matter intake was restricted to 1.5% BW. Diets were fed as TMR (at 9.00 a.m. and 2.30 p.m.) throughout the entire experimental period. From day 21 prior to the expected calving to day 21 of lactation, all cows were fed the same fresh lactating diet (0.82 UFL, 35% NDF, 16.4% CP) to provide the adequate nutrients for cows with a body weight of 650 kg and 30 L of daily milk production. The ingredients and nutrient contents in the diets are shown in Table 1. Body condition of cows (point scale: 1 - very bad, 5 - very good) was scored on -56 d, -21d, and at a day of calving. In the far-off period, the cows were housed in group box stalls, and three weeks before the expected calving they were moved until parturition to individual maternity pens. Daily dry matter intake during the far-off period was measured in groups and individually in transition period. Calves were separated from their mothers 2 h after birth and were placed in the individual pens in plastic sheds. The ADLIB group composed of 12 heifer calves and six

bull calves, whereas the REST group comprised of 13 heifers and five bulls. The calves were weighed 2 h after calving (day 0 - initial weight) and on day 21 of life (final weight). For the first 3 d, they were fed colostrum and transition milk in the amount of 10% of body weight. Throughout the rest of the experimental period (4 d to 21 d), the calves received daily 5.0 L of whole milk (2 x 2.5 L at 8.00 a.m. and 2.00 p.m.) and were fed starter mixture *ad libitum*, composed of protein concentrate (LNB Poland, 30% of CP, 1.02 UFL/ kg) and whole maize grain (77/23 wt/wt). Animals had constant access to fresh water.

Sampling procedures and analysis. Samples of colostrum were collected from cows within 2 h after parturition. Blood samples from the jugular vein were collected from the calves on the 3rd and 21st d of life into two test tubes with a coagulant and were centrifuged. The separated serum was frozen at -20°C and stored until analysis. In all colostrum samples, the density (DMA 35N Density Meter), protein and lactose content (Infrared Milk Analyzer 150, Bentley Instruments Inc.), somatic cell count (Somacount 150, Bentley Instruments Inc.), and urea concentration (ChemSpec 150, Bentley Instruments Inc.) were measured. In the colostrum and blood serum samples, the concentration of immunoglobulins (IgG, IgA, IgM) was determined by ELISA kits (Bethyl Inc.).

Table 1
Ingredients (% of diet's DM) and nutritive value of the experimental diets (TMR)

Ingredients (% of DM)	Far-off diet	Close-up and fresh diet
Wheat straw	34.5	-
Soybean meal	4.1	10.0
Alfalfa silage	18.0	11.0
Maize silage	42.1	20.8
Grass silage	-	10.8
Maize grain silage	-	9.7
Sugar beet pulp silage	-	5.5
Brewer's grain silage	-	8.2
Hay	-	5.2
Barley grain	-	7.1
Triticale grain	-	5.5
Glycerol	-	1.3
Mineral-vitamin premix	1.3	4.9
Nutrient concentration (in 1 kg DM)		
UFL *	0.69	0.82
PDIN (g) **	66	97
PDIE (g) **	70	98
Crude protein (%)	11.4	16.4
NDF (%)	53.3	35.3
ADF (%)	34.1	20.3
Ca (g)	7.1	7.4
P (g)	3.3	3.7

* UFL – feed unit for lactation (net energy), ** PDIN, PDIE - protein digestible in the small intestine when rumen fermentable nitrogen or energy are limited, respectively.

The concentration of the insulin-like growth factor-1 (IGF-1) was determined by radioimmunoassay (Diagnostic Systems Laboratories Inc., USA). Total protein and albumin concentrations were determined using Pentra 400 (Horiba ABX). Results were analysed statistically by the Student's *t*-test using the SAS computer software SAS 9.1 (2004) and the PROC T-TEST procedure. Significance was declared at $P \leq 0.05$.

Results

The average daily dry matter intake in the far-off period was 12.9 kg (2.0% BW) and 9.9 kg (1.5% BW) in ADLIB and REST groups, respectively. Body condition score (BCS) of cows were similar in both groups at the beginning of dry period (mean 3.58 points) and decreased during the far-off period by 0.02 points in the

ADLIB and 0.08 points in the REST group. Lower feed intake in the far-off period did not have a statistically significant influence ($P > 0.05$) on the parameters characterising the quality of colostrum (Table 2). The mean total Ig concentration in colostrum was 50.6 and 52.6 g/L for ADLIB and REST group, respectively. Similarly, no differences ($P > 0.05$) occurred between the groups in regard to the remaining parameters of colostrum quality: content of fat, protein, lactose, urea, and the somatic cell count. The mean total antibody concentration in the blood serum of calves from the ADLIB and REST groups 3 d after birth was similar and amounted 19.8 g/L and 20.3 g/L, respectively (Table 3). On the 21st d the concentrations of total immunoglobulins, IgG, and IgA were significantly higher ($P < 0.05$) in REST group compared to ADLIB group.

Table 2
Colostrum chemical composition and immunoglobulin concentration

	Unit	ADLIB	REST	SEM	P-value
Density	g/cm ³	1.059	1.061	0.002	0.65
Fat	%	5.41	4.03	0.50	0.17
Protein	%	10.8	11.2	0.45	0.65
Lactose	%	1.51	1.52	0.17	0.98
Urea	mg/mL	197	162	23.2	0.46
SCC	1,000/mL	1,963	1,765	464	0.84
Ig total	g/L	50.6	52.4	3.28	0.79
IgG	g/L	44.0	45.4	3.10	0.82
IgM	g/L	5.93	6.25	0.48	0.75
IgA	g/L	0.625	0.695	0.10	0.73

SEM - standard error of the mean.

Table 3
Calf serum concentration of immunoglobulins (g/L) and IGF – 1 (ng/mL)

	Day of life							
	3				21			
	ADLIB	REST	SEM	P-value	ADLIB	REST	SEM	P-value
Ig total	19.8	20.3	0.77	0.77	14.7 ^b	19.7 ^a	1.01	0.01
IgG	17.5	18.2	0.74	0.62	12.8 ^b	17.2 ^a	1.00	0.02
IgM	1.81	1.62	0.09	0.32	1.55 ^b	1.99 ^a	0.10	0.03
IgA	0.617	0.512	0.06	0.40	0.412	0.576	0.05	0.08
Albumin	26.4	26.6	0.23	0.73	28.0	27.7	0.31	0.65
Globulin	26.2	30.0	1.62	0.25	21.5	23.2	0.92	0.37
Protein	52.9	56.6	1.62	0.23	49.5	50.9	1.04	0.51
IGF – 1	103	110	17.1	0.76	152	167	14.3	0.62

SEM - standard error of the mean,

a, b – means within a row with different superscripts differ at $P \leq 0.05$.

Table 4
Body weight at birth (kg) and average daily gain (g) of calves during the first 21 d of life

Item	ADLIB	REST	SEM	P-value
Body weight at birth	45.1	45.4	0.83	0.84
Daily gain	175	143	20.6	0.45

SEM - standard error of the mean.

No significant effect of dam nutrition in the far-off period on the concentrations of albumins, globulins, total protein, and IGF-1 was found on days 3 and 21 of the calves' life. The newborn calves body weights were very similar in both groups (mean 45.25 kg). The average daily gain, measured during the first 21 d of life, was slightly higher in ADLIB (175 g) compared to REST (143 g) group; however, the differences were not significant (Table 4).

Discussion

Although, the importance of dry cow nutrition in close-up period has been documented (31), little has been reported regarding the implications of decreasing energy intake in the far-off dry period on immunological status of calves. Poor prepartum management during the dry period has been related to calf immune response (23). In the current study colostral Ig concentration were not affected by the maternal diet in far-off period and were only somewhat higher than the minimum recommended level (50 g/L). Recently Furman-Frątczak *et al.* (8) in the long term study in Poland found higher average Ig concentration in colostrum (79.48 g/L). Gulliksen *et al.* (12) reported that in Norwegian dairy cows more than 57.8% of colostrum samples have immunoglobulin concentrations <50 g/L. Significant differences of immunoglobulin concentration in serum were not detected among treatments on day 3 of rearing, suggesting that the ability of newborn calves to absorb colostral Ig was not affected by maternal nutrition. Despite the relatively low colostrum Ig concentration, the level of serum IgG in both groups of calves was higher than 17 g/L, which indicated adequate passive immunity. Wells *et al.* (30) reported that mortality rates of calves with serum IgG higher than 10 g/L were more than two times lower those of calves with lower IgG plasma concentration. In a previous study, Stockdale and Smith (28) reported that the increased energy intake in the last month of gestation reduced the concentration of total Ig in colostrum without the negative effect of restricted feeding on colostral Ig. According to Olson *et al.* (20) and Halliday *et al.* (13), restricted maternal diet may not affect the passive immunity in calves. On the contrary, Hough *et al.* (17) demonstrated that although colostral IgG concentrations were not significantly affected by nutritional treatment, in the calves' serum from restricted fed cows, Ig tended to have lower concentrations. They suggested that maternal nutritional restriction may alter some constituent of the colostrum and affect the immunoglobulin absorption. Burton *et al.* (3) has noted no differences in immunoglobulin concentrations in the colostrum of cows fed a restricted diet; however, absorption of immunoglobulins was reduced. Lake *et al.* (19) suggested the decreasing absorption in calves from restricted fed cows may depend on the timing of nutrient restriction during the dry period. No significant effect of nutrition ($P>0.05$) in the far-off period on the concentration of albumins, globulins, total protein, and IGF-1 in the blood serum

was found on the 3rd and 21st d of the calves' life. However, in the calves' serum from cows fed *ad libitum* (group ADLIB) during the far-off dry period on day 21 of rearing, total Ig, IgG, and IgM concentrations were significantly lower. Devery *et al.* (5) found that endogenous immunoglobulin production began about 36 h after calving and lasts up to 3rd week of age, however, the rate of production approximately 1 g of IgG per day seemed to be too low to affect IgG at day 21 of rearing. Furman-Frątczak *et al.* (8) suggested that Ig level in the 3rd or 4th week compared to Ig concentration in the 48th h of calf life could be a good measure of the humoral postcolostral calves' immunity against the infection. Decrease in all the immunoglobulin classes before 5th week of life may indicate an appropriate passive protection of calves, while increased Ig in serum in that period is the consequence of too early active response of immune system to infections. Insulin-like growth factor-1 is a key regulator of growth and stimulates small intestine development neonates of several species, including calves (27). The nutritional status of animal has a large impact on the concentrations of IGF-1 in blood serum (2). In the present study, the maternal diet in the far-off period did not significantly affect IGF-1 serum concentration on both the 3rd and 21st d of the calves' life. IGF-1 level in blood serum increased approximately by 50% on the 21st d compared to the 3rd d of rearing. Hammon and Blum (14) showed a six-fold higher IGF-1 content in the serum of calves, which were given colostrum as compared to calves fed a milk replacer during the first week of life. Pagano *et al.* (21) observed a lower IGF-1 level in the serum of hypertrophic animals, which may suggest a negative relationship between the body weight and IGF-1 level in the serum. Hammon *et al.* (15) demonstrated a lower IGF-1 level in the serum of calves having free access to the colostrum and milk, with higher daily gains during the first month of life. In the current study, similarly to the other results (4, 6, 31), the mean birth weights of calves and daily weight gain were not different among the treatments. The average weight of newborn calves (45.25 kg) was higher than in the study by Furman-Frątczak *et al.* (8) where the mean birth weight was 39.8 kg. In the actual study, the average daily gain during the first three weeks of rearing was lower than the optimal growth for Holstein-Friesian calves; however, it was higher than in recently published results (9, 10). In a similar study, Silva-del-Rio *et al.* (26) demonstrated that, despite differences in nutrient intake in the far-off period, calf birth weight was not affected. Roche *et al.* (24) found no relation between different pre-calving dry matter intake at 1.3%, 1.9%, 2.4%, and 2.6% BW and calf birth weight. Grum *et al.* (11) suggested that maternal body reserves are mobilised to support growth during negative energy balance. These data indicate that low intake of dry matter in the far-off period did not negatively affect calves' weight. High intake of dry matter fed throughout the dry period did not affect mean birth calves' weight. Dann *et al.* (4) also found no difference in calf birth weight from cows despite the difference in dry matter intake during far-off and close-up periods.

We conclude that limiting the maternal diet during the far-off period did not affect negatively the colostrum quality or calves' immune status during early stages of life. Further studies will be required to elucidate the effect of shortening or omitting the dry period on health status of calves.

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