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The effect of different types of feed ration on the adaptation of the peripartum period in dairy cows

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Abstract: *The objective of this study was to evaluate the effect of forage type and concentrated type of feed rations in the antepartum period (three weeks before calving) and in the postpartum period (three weeks after calving) on rumen fermentation and intermediate metabolism in dairy cows.*
The limited content of starch and non-fiber carbohydrates in the straw diet before calving directly correlates with increased values of pH, acetic acid, and reduced values of propionic acid in the rumen content, as well as an increased value of non-esterified fatty acids and liver enzymes in the blood serum. This state of metabolism indicates a negative energy balance, where the transplacental transfer of glucose for the development of the fetus is not compensated by energy intake, and increased lipomobilization with symptoms of metabolic load on the liver confirms the insufficient adaptation in close-up dairy cows. The optimal representation of energy in the adaptation diet before calving directly correlates with the values of rumen content and blood serum and confirms optimal adaptation before calving.

I. INTRODUCTION

The peripartum period resp. transition is defined as the period from 3 weeks before parturition until 3 weeks postpartum. It is characterized by changes in endocrine status and major alterations in the requirement for nutrients, vitamins, and minerals [1].

The peripartum period in dairy cows is accompanied by morphological and functional changes in the rumen and changes in the regulation of nutrient metabolism due to the increasing demands of energy, glucose, amino acids, and calcium for the pregnant uterus and mammary gland [2]. Increased energy intake in the form of starch before parturition compared to feed ration during the dry period supports morphological and functional adaptation of the rumen [3]. Increased synthesis of propionic acid by promoting gluconeogenesis maintains a positive energy balance before parturition [4 – 5] and significantly regulates metabolic adaptation, lipomobilization, and ketogenesis after parturition [6]. The disadvantage of increased energy intake before parturition is the risk of energy overfeeding in obese dairy cows, increased lipomobilization after parturition, and increased incidence of displaced abomasum in dairy cows [7 – 8]. To prevent energy overfeeding before parturition, a system of feeding dairy cows with a uniform ration throughout the dry period with reduced intake of energy was proposed [9]. This type of feed ration (goldilocks diet, straw diet) with an increased content of straw reduces the risk of energy overfeeding, promotes dry matter intake, and prevents lipomobilization and the development of metabolic diseases [10]. Cereal straws, particularly wheat and barley straws, are well-suited to dilute the concentration of energy when corn silage is the predominant forage source available [11]. The disadvantage of this feed ration is the issue of rumen adaptation and metabolism before calving.

The objective of this study was to evaluate the nutritional influence of feed rations in the peripartum period with different proportions of starch on the rumen adaptation, stability of fermentation, and intermediate metabolism of dairy cows.

II. Material and Methods

2.1 Sampling

This study included Holstein dairy cows in the antepartum period (21 days before calving, n = 18) and the postpartum period (21 days after calving, n = 18), which were selected for the experimental group and fed with a forage type of feed ration (straw diet), and dairy cows in the control group, which were fed with a concentrated type of feed ration. We evaluated the effect of different types of feed rations in the peripartum period on rumen fermentation and intermediate metabolism in dairy cows.

The composition of feed rations is summarized in Table 1. The experimental diet in the antepartum period was based on forages with the addition of straw, and the feed ration in the postpartum period was enriched with the addition of concentrated feeds (grains and protein feeds). The control diet in the antepartum and postpartum periods consisted of forages and the addition of concentrated feeds.

Table 1 The composition of the experimental and control diets in the antepartum and postpartum periods

	Experimental group		Control group	
Items	Antepartum	Postpartum	Antepartum	Postpartum
Corn silage (kg)	15.0	23.0	17.0	17.0
Grass silage (kg)	6.0	12.0	-	-
Alfalfa silage (kg)	-	-	5.0	10.0
Barley straw (kg)	3.0	-	-	-
Soybean meal (kg)	-	1.5	0.5	1.5
Rapeseed meal (kg)	-	2.0	1.0	1.0
Corn bran (kg)	-	3.3	2.0	3.5
Wheat bran (kg)	-	-	1.5	2.5

2.2 Laboratory analyses

The samples of the feed rations were taken from the feed manager and were analyzed for dry matter (DM), which consisted of crude protein (CP), fat, acid and neutral detergent fiber (ADF, NDF), and starch analyzed by conventional methods according to Commission Regulation (EC) no. 152/2009 [12]. The DM was determined by weight upon drying the sample at 105 °C under the prescribed conditions. The CP content was determined by the Kjeldahl method using a 2300 Kjeltec analyzer Unit (Foss Tecator AB, Sweden). The fat was determined by the device Det-Gras (JP Selecta, Spain). The ADF and NDF were determined using a Dosi-Fiber analyzer (JP Selecta, Spain), and the starch content was determined polarimetrically. The net energy for lactation (NEL) and non-fiber carbohydrates (NFC) were calculated according to the nutrient requirements of dairy cattle [13].

Samples of rumen content intended for analysis of the fermentative and synthesizing capacity of the rumen were taken 4–5 hours after feeding by stomach cannulas. Volatile fatty acids (VFA) in the rumen content were determined in a two-capillary isotachophoretic analyzer EA100 (Villa Labeco, Slovak Republic). The pH of the rumen content was determined potentiometrically with a portable electronic pH meter (JP Selecta, Spain).

The intermediate metabolism was assessed by analyzing energy metabolism (non-esterified fatty acid (NEFA)) and liver status (aspartate aminotransferase (AST), cholesterol, and bilirubin) in the blood serum of dairy cows. Blood samples were collected 6 hours after feeding. The analysis of cholesterol and AST was performed using commercially available kits on biochemical analyzer Ellipse and NEFA, according to Ducomb.

2.3 Statistical analyses

The results were processed using the statistical program SPSS Statistical Software version 24.0 (IBM Corp., Armonk, NY, USA) and expressed as mean (x) and standard deviation (SD). The non-paired Student's t-test was used in the work to compare the results of rumen and blood metabolites in experimental and control diets in the antepartum and postpartum periods.

III. Results and Discussion

The nutritional contents of experimental and control diets in the antepartum and postpartum period are summarized in Table 2. The experimental diet in the antepartum period with a reduced starch content (15.9%), NFC (31.3%), and NEL (6.0 MJ) in DM limits energy intake below the standard requirement [13] before calving. The control diet shows a starch content of 25.5% and NFC 38.5% in the upper third of the standard requirement in the period three weeks before calving [13] and confirms the optimal energy intake before calving and thus the adaptation and stabilization of rumen metabolism to a concentrated type of feed ration after calving.

Table 2 Nutritional contents of experimental and control diets in the antepartum and postpartum periods (% in DM)

	Experimental group		Control group	
Items	Antepartum	Postpartum	Antepartum	Postpartum
DM [1] (%)	40.9	42.7	43.0	44.4
CP [2] (%)	12.5	15.8	14.5	15.9
Fat (%)	2.8	5.9	3.2	4.0
NDF [3] (%)	47.7	28.0	37.0	32.0
Starch (%)	15.9	27.8	25.5	27.8
NFC [4] (%)	31.3	42.4	38.5	43.5
NEL [5] (MJ)	6.0	7.1	6.5	6.9

[1] - dry matter, [2] - crude protein, [3] - neutral detergent fiber, [4] - non-fiber carbohydrates, [5] - net energy for lactation

The analyzed values of rumen fermentation are summarized in Table 3. In the experimental diet in the antepartum period, it was confirmed that there was a significantly decreased VFA ($P < 0.01$), a reduced proportion of propionic acid (C_3) ($P < 0.01$), an increased proportion of acetic acid (C_2) ($P < 0.01$), increased acetic acid C_2:C_3 ratio ($P < 0.01$), and an increased pH ($P < 0.01$) compared to the control diet in the antepartum period. The results confirm the fermentation of the forage type of feed ration before calving, with insufficient adaptation to the concentrated type of feed ration after calving which was affected by the limited content of starch and NFC in the experimental diet before calving. In the experimental diet in the postpartum period, reduced values of pH ($P < 0.01$), C_2 ($P < 0.01$), C_2:C_3 ratio ($P < 0.01$), and increased values of C_3 ($P < 0.01$), and VFA ($P < 0.01$) compared to the antepartum period were confirmed. These results point to reduced rumen adaptation in the antepartum period and a sudden transition from a forage type of feed ration to a concentrated type after calving. The optimal values of rumen fermentation in the control diet in the antepartum period point to the sufficient adaptation of the rumen in this period. The aim of nutrition in the transition period is to increase the content of starch in the form of grains (wheat, barley) to support the adaptation of rumen fermentation, which includes morphological changes associated with the proliferation of rumen papillae and an increase in their absorption surface and functional changes in the rumen epithelium [14 – 15].

Table 3 The level of rumen fermentation in the experimental and control diets in the antepartum and postpartum periods

	Experimental group		Control group	
		$x^1 \pm SD^2$		
Rumen content	Antepartum	Postpartum	Antepartum	Postpartum
pH	$6.9\pm0.2^{a,b}$	6.1 ± 0.2^{b}	6.4 ± 0.3^{a}	6.1±0.3
C_2 [3](mmol/l)	$83.8\pm6.2^{c,d}$	80.5 ± 3.71^{d}	68.5 ± 8.3^{c}	85.2±8.2
C_3 [4] (mmol/l)	$14.5\pm3.1^{e,f}$	32.2 ± 3.5^{f}	29.2 ± 3.8^{e}	36.8±5.3
C_4 [5] (mmol/l)	11.2±1.5	17.5±0.7	17.6±2.1	19.5±1.0
∑ VFA[6](mmol/l)	$94.3\pm12.7^{g,h}$	130.3 ± 7.1^{h}	130.5 ± 11.6^{g}	141.6±13.3
C_2:C_3	$4.8\pm0.5^{i,j}$	2.5 ± 0.2^{j}	2.9 ± 0.2^{i}	2.3±0.2

[1-] means, [2-] standard deviation, [3-] acetic acid, [4-] propionic acid, [5-] butyric acid; [6-] volatile fatty acids, Means in line with the same letter are significantly different ([a,b,c,d,e,f,g,h,i,j] $P < 0.01$)

The analyzed indicators of blood serum are summarized in Table 4. Significantly higher NEFA values ($P < 0.05$) above the upper limit of the reference range in the antepartum period (NEFA > 0.3 mmol/l) were confirmed in dairy cows fed the experimental diet, which confirms the negative energy balance and increased lipomobilization [16]. Increased values of AST ($P < 0.05$) and bilirubin ($P < 0.05$) in the postpartum period, when fed the experimental diet compared to the control diet confirm the increased metabolic load on the liver function in dairy cows with signs of fat infiltration caused by increased lipomobilization, which is conditioned by insufficient adaptation of rumen and intermediate metabolism when feeding forage type of feed ration in the antepartum period. The optimal values of blood markers in the control diet in the antepartum period point to the optimal adaptation of dairy cows in this period. According to Goff and Horst [16], to prevent diseases, adaptation of the rumen to a concentrated diet with a high energy density must be ensured during the peripartum period.

Table 4 Blood markers in experimental and control diets in the antepartum and postpartum periods

	Experimental group		Control group	
		$x^1 \pm SD^2$		
Blood serum	Antepartum	Postpartum	Antepartum	Postpartum
Cholesterol (mmol/l)	2.1±0.4	3.0±1.4	2.5±0.4	2.6±0.6
NEFA [3] (mmol/l)	0.4 ± 0.1^{a}	0.5±0.1	0.3 ± 0.1^{a}	0.4±0.1
AST [4] (µkat/l)	1.4±0.2	1.9 ± 0.3^{b}	1.3 ± 0.1^{b}	1.6±0.1
Bilirubin (µmol/l)	4.5±1.3	5.9 ± 0.9^{c}	2.9 ± 0.8^{c}	3.6±0.9

[1-] means, [2-] standard deviation, [3-] non-esterified fatty acids, [4-] aspartate aminotransferase, Means in line with the same letter are significantly different ([a,b,c] $P < 0.05$)

IV. Conclusion

Many different nutrition programs can be successful during the transition period. However, high-straw rations are exciting for their potential to markedly improve health during the transition period. Straw has many desirable characteristics that seem to improve the health and digestive dynamics of the rumen. The slow digestion and passage rate of straw certainly seem to be important in the prevention of displaced abomasum. The results from this study show the impact of the straw diet on rumen fermentation and intermediate metabolism in dairy cows. However, results confirmed reduced rumen adaptation with a risk of a metabolic load on the liver in dairy cows fed with forages during the all-dry period.

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