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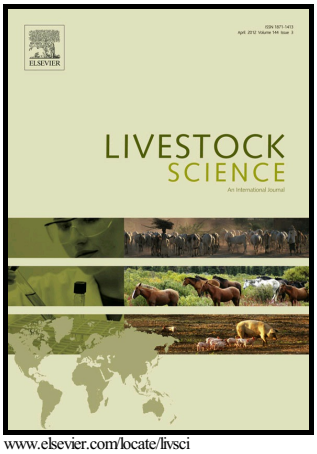

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Feeding behaviors, metabolism, and performance of primiparous and multiparous dairy cows fed high-concentrate diets

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ABSTRACT

Currently, there is a trend in management practices to feed a high concentrate diet to sustain a high level of milk production. The objective of this study was to identify the differences between primiparous (PP) and multiparous (MP) dairy cows fed a high-concentrate diet on feed intake and behavior, rumen pH and rumen fermentation, blood metabolites, inflammation, and milk production and efficiency. Twenty-four PP (DIM = 114 ± 20; 43.2 ± 10.6 kg/d of milk; mean ± SD) and fifty-four MP (DIM = 99 ± 30; 53.2 ± 13.6 kg/d of milk) cows were fed a high-concentrate diet consisting of 35% forage and 65% concentrate mix. The study lasted for 24 d, which consisted of 14 d of environmental adaptation followed by 10 d of data collection. Rumen pH was measured via rumenocentesis for all cows and reticuloruminal pH was measured for a subset of animals (4 PP and 10 MP) using indwelling oral-administered sensors. The PP cows had greater sorting against long particles during the daytime, but greater sorting in favor of long particles at night. The dry matter intake (DMI) between 0 and 4 h after the morning feeding was

not affected by parity, whereas PP cows had greater DMI from 4 to 6 h post-feeding and MP cows had greater DMI from 6 to 24 h post-feeding. Total 24-h intake was greater (25.1 vs. 22.4 kg/d) in MP than in PP. Rumen pH and fermentation profile were not affected by parity. Duration of rumen pH <5.8 measured 750 and 570 ± 231 min/d for PP and MP cows, respectively, which indicates that cows experienced rumen acidosis with respective coefficients of variation measuring approximately 8.2 and 10.8%, respectively. Primiparous cows produced less milk (-6.3 kg/d), 3.5 % fat corrected milk (-4.2 kg/d), milk protein (-0.160 kg/d), and lactose (-0.230 kg/d). The PP cows, despite lower production, had greater concentrations in plasma of cholesterol, ß-hydroxy-butyrate (BHBA), and blood urea nitrogen and a trend for greater triglyceride than MP cows. Primiparous cows also had lower feed efficiency compared with MP (1.88 vs. 2.03). We conclude from these results that under conditions of the present study, PP dairy cows responded with lower feed efficiency and greater concentration of cholesterol, BHBA, and urea nitrogen in the blood.

Keywords:

parity, high-concentrate diet, metabolic stress, efficiency

1. Introduction

In order to remain profitable, modern dairy farms have to focus on increasing feed efficiency. Feeding high-concentrate diets (i.e., 60 % of DM) is a relatively easy way to improve feed efficiency (Beauchemin et al., 2008). Therefore, this type of diet is fed commonly in modern large-scale dairy farms (Beauchemin et al., 2008; Alqaisi et al., 2014) and recently some commercial Iranian dairies have fed up to 70 % concentrate (Esmaeili et al., 2016). However, it

is not clear to what extent dairy cows can sustain the greater metabolic stress accompanied by feeding high-concentrate diets.

There is evidence that hepatic function in mid-lactation dairy cows can adapt to metabolic changes during feed restriction (Gross et al., 2013). However, mid-lactation primiparous (PP) dairy cows might be more susceptible to metabolic changes such as high-concentrate diets than multiparous (MP) cows. A possible factor for such contrast between PP and MP cows could be their differential feeding pattern behaviors. Previous studies reported that PP cows have a greater ability to select long particles in the diet (DeVries et al., 2011), and have lower DMI, milk production (Azizi et Al., 2009; DeVries et al 2011), and rumen pH (Humer et al., 2015). To our knowledge, however, no study has investigated the effect of parity (i.e., PP vs. MP cows) on metabolism and feeding behavior in cows fed a high dietary proportion of concentrates (i. e. 65 %). It is possible that the first lactation cow that have not been exposed to pervious lactation and longtime feeding high-concentrate diets until after calving (Penner et al., 2007) may have a different behavior and metabolism compared with MP cows. We hypothesized that concentrations of metabolites in blood of PP cows could be different from MP cows, and that the metabolic status could affect feed efficiency. Therefore, the objective of this study was to evaluate the differences in feeding behavior, rumen pH and fermentation, blood metabolites, milk production, and feed efficiency between PP and MP cows fed high-concentrate diets.

2. Materials and methods

2.1. Animals, diets, and study design

Animal care and husbandry was conducted according to the guidelines of the Iranian Council of Animal Care (1995), and the study was approved by the Institutional Animal Care Committee for Animals Used in Research. Twenty-four PP (DIM = 114 ± 20 with a range of 83

to 149 DIM]; average milk production = 43.2 ± 6.2 kg/d; BW = 571 ± 52 kg; mean ± SD) and 54 MP (DIM = 99 ± 30 with a range of 55 to 158 DIM]; average milk production = 53.2 ± 13.6 kg/d; BW = 667 ± 67 kg; mean ± SD) mid-lactation Holstein cows were used in this study. The number of animals in each group was the maximum number of cows available at the dairy farm. Cows were enrolled in the study based on DIM during 3 consecutive 24 d period with a group of 26 cows (8 PP and 18 MP) in each period. Cows were fed ad libitum a diet consisting of 35% forage and 65% concentrate mix (DM basis; Table 1). The study period was 24 d long including 14 d of diet adaptation and 10 d of data and sample collection. The diet was similar to the diet that cows were fed prior to the start of the study. For individual monitoring, cows were housed in individual stalls (4 × 4 m) within a roofed facility with open sides and clean wood shavings, and dry manure were used for bedding and refreshed daily. Cows were fed twice daily at 1000 h and 1800 h, and had free access to water. Feed was offered at 105 to 110% of actual feed intake of the previous day. Cows were milked three times daily at 0100, 0900, and 1700 h in a herringbone milking parlor.

2.2. Rumen pH and fermentation profile

During the last 2 d (i.e., 23 and 24 d) of the study period, half of the cows in each day were sampled via rumenocentesis for rumen fluid from the ventral sac at approximately 4 h after the morning feeding (Nordlund and Garrett, 1994). The pH of rumen fluid was determined immediately by using a portable, digital pH meter (HI 8318, Hanna Instruments, Cluj-Napoca, Romania) calibrated at pH 4 and 7. Samples of ruminal fluid were collected with a stomach probe at approximately 4-h post-feeding for measuring the VFA profile on d 21 and 22 of each study period for half of the cows in each day. Approximately the first 100 ml of fluid were

discarded and 50 mL of secondary sample was strained through one layer of cheesecloth, and then 4 mL of ruminal fluid was acidified with 1 mL meta-phosphoric acid 25%, stored at -10°C until VFA analyses. Ruminal fluid samples were analyzed for VFA profile by gas chromatography (Philips, PU 4410, USA) according to the method described by Ottenstein and Bartley (1971).

A subset of 14 of 26 cows (4 PP and 10 MP) in the final period were used to continuously monitor rumen pH and temperature with an indwelled wireless pH-transmitting unit (eBolus, eCow Ltd., Exeter, Devon, UK) that was previously validated for these measurements (Mottram et al. (2008). The detailed description of this device has been reported by Mottram et al. (2008) and Falk et al. (2016). In brief, the device is a wireless telemetry device that records pH and temperature continuously for up to 6 months, according to the manufacturer's manual. The eBolus is 115 mm long, has a diameter of 27 mm, and weighs 200 g (Mottram et al., 2013). The eBoluses are factory calibrated with calibration solution of pH 4 and pH 7. The units measured pH and temperature every 15 min, and data for both pH and temperature were collected using an analog-to-digital converter and stored in an external memory chip. The measurements were taken continuously during the final 5 d of study. Data for pH were analyzed as daily mean pH and time (min/d) below specific cut-off points (5.8 and 6.0).

2.3. Chemical analyses and DMI

Samples of TMR and orts were collected during d 15 to 20 of the study period and ort samples were composited by cow. The TMR and orts samples were dried at 60°C in a forced-air oven for 72 h and ground to pass a 1-mm screen using a rotary mill (Retsch GmbH 5657 HAAN, Germany). Chemical analyses were performed in duplicate (except one replication for FA). Samples were analyzed for CP (method 955.04; AOAC, 2002), ether extract (method 920.39;

AOAC, 2002), and the NDF and ADF were sequentially analyzed (Van Soest et al., 1991) with heat stable alpha-amylase and sodium sulfite used in the NDF procedure. The ash content of samples was determined at 620°C for 8 h. The NFC content was calculated as 100 − (% NDF + % CP + % fat + % ash). During d 15 to 20 of the study, daily DMI was determined for each cow as the difference between TMR offered and orts weighed daily, with samples collected daily for the determination of DM content.

2.4. Determination of particle size, sorting activity, and feeding behavior

During d 15 to 20 of the study, TMR and orts were sample daily for determination of particle size (PS). The PS of these samples was measured in triplicate using the Penn State Particle Separator (PSPS) equipped with 3 sieves and a bottom pan (Kononoff, 2002). After sieving, samples were placed in a forced air oven at 60°C for 72 h to determine DM of each sieved fraction. Physically effective factor (pef) values were determined as the total proportion of DM retained on the 19 and 8 mm sieves (pef8, Lammers et al., 1996) or on the 19, 8 and 1.18 sieves (pef1.18; Kononoff, 2002) (Table 2). The peNDF was calculated by multiplying pef8 and pef1.18 by the NDF content of the diet (DM basis) to obtain peNDF8 and peNDF1.18, respectively. During d 15 to 20 of the study, a sorting index was used to score cows as according to methods described by Leonardi and Armentano (2003). The index was also used for correcting peNDF. During two consecutive days between d 15 to d 20 of the study, feed bunk contents for each animal were weighed and sampled at 2, 4, 6, and 24 h after the morning feeding to determine PS after feeding and the fractional DMI during the day.

2.5. Blood sampling and analyses

Blood samples (7 mL) were collected 3 h after the morning feeding, for one day between d 15 and 20 of the study, via the coccygeal vein using an evacuated tube without anticoagulant and

a heparinized evacuated tube. Blood samples were placed on ice immediately after collection and centrifuged at 3,000 × *g* for 15 min. Serum and plasma samples were separated and stored in plastic tubes frozen at −10°C until analysis. The concentrations of serum glucose, cholesterol, blood urea-N (BUN), high density lipoprotein (HDL) cholesterol, triglyceride (TG), total protein, albumin, creatinine, aspartate aminotransferase (AST), and alkaline phosphatase (ALP) were measured by an autoanalyzer (Abbott Alycon 300, USA) using commercial kits (Pars Azmoon Co., Tehran, Iran) according to the manufacturer's instructions. Before application, the autoanalyzer was calibrated with the control sera N and P (TrueLab N® and TrueLab P®, respectively; Pars Azmoon Co., Iran) and a calibrator solution (TrueCal U®, Pars Azmoon Co., Iran). Serum ß-hydroxy-butyrate (BHBA) and nonesterified fatty acid (NEFA) were determined by commercial colorimetric kits (Randox Laboratories Ltd., Ardmore, UK) using the same autoanalyzer. Globulin concentrations were calculated by subtracting albumin concentrations from total protein. Concentration of serum amyloid A (SAA) in plasma was determined by using an ELISA bovine kit (Shanghai Crystal Day Biotech Co., China) according to manufacturer's instructions. BUN, AST and BHBA were detected at 340 nm, ALP was detected at 405 nm, SAA was detected at 450 nm, cholesterol, HDL, and TG were detected at 500-520 nm, and glucose, total protein, albumin, creatinine and NEFA were detected at 550 nm. The intra-assay variation was controlled by limiting the coefficient of variation to ≤12% for SAA and ≤5% for other measurements.

2.6. Milk yield and components, body weight and body condition score

Milk yield was recorded during d 15 to 20 of the study and milk samples were collected from each milking during d 15 to 18. Milk samples were preserved with potassium dichromate and stored at 4°C until further analysis for fat, true protein, lactose, and solids not fat content

(Fossomatic5000, Foss Electric, Hillerød, Denmark). Milk yield was corrected for milk components as 3.5% fat corrected milk (Gaines, 1928), energy corrected milk (Jenkins et al., 1998), and solid corrected milk (Tyrrell and Reid, 1965).

Cows were weighed at the beginning (d 4) and the end of each period (d 21) and body condition score (BCS) was determined at the end using a five-scale method where 1 = emaciated and 5 = obese (Ferguson et al., 1994). Also, at the end of study back fat thickness (BFT) was measured using a portable B-mode ultrasound generator (SonoVet 600V, BCF Technology Ltd., West Lothian EH54 9BJ, Scotland, UK) with a linear transducer and a frequency between 5.0 and 6.5 MHz (Schroder and Staufenbiel, 2006).

2.7. Statistical analysis

Data were analyzed for normality using the Shapiro-Wilk test. Data that were not normally distributed were log transformed to achieve a normal distribution. After transformation, relative data were rechecked for normality that was achieved. The ANOVA was performed using Mixed procedure of SAS (version 9.1, SAS Institute Inc., Cary, NC) with lactation (i.e., MP vs PP) as the fixed effect of parity and random effect of group (the group of allocation of cows to study). For rumen pH, VFA profile, feeding behavior and performance data effect of DIM was included as covariate in the final model only if significant ($P \leq 0.05$). The DIFF option was used in each of the comparisons. All reported values were LS means, and significance was declared at $P \leq 0.05$, and a trends at $P \leq 0.10$.

3. Results

Feed intake from 0 to 2 h or 2 to 4 h after morning feeding was not different ($P > 0.08$) between PP and MP cows, whereas the intake from 4 to 6 h was greater ($P < 0.01$) for PP cows than for MP cows, and during 6 to 24 h of after feeding, PP cows ate 2.6 kg less ($P < 0.01$) feed

than did MP cows (Table 2). As a result, daily DMI, from 0 to 24 h after feeding, was lower ($P < 0.01$) for PP than for MP cows.

Feed sorting measurements are presented in Table 3. From 0 to 6 h after morning feeding, PP cows consumed a greater ($P = 0.02$) amount of particles between 8 and 19 mm (sorting index of 92 vs. 95). However, later after feeding (e. g., 6-24 h) PP cows consumed greater ($P = 0.02$) amount of particles between 8 to 19 mm than MP cows (sorting index of 101 vs. 99). In contrasts, PP cows consumed less ($P = 0.03$) fine particle (< 1.18 mm) than MP during 6 to 18 h post-feeding. However, sorting index for all particles of PSPS sieves during entire 24 h period was not different ($P > 0.10$) between PP and MP cows.

The rumen pH and VFA profiles for PP and MP cows are presented in Table 4. There was no difference ($P > 0.10$) between PP and MP cows in mean, max, and min pH or duration of pH below 6.0 or 5.8. Moreover, PP and MP cows had no differences ($P > 0.10$) in total VFA concentration in the rumen as well as the percentage of VFA profile with the exception of butyrate, which tended ($P = 0.08$) to be greater in PP than in MP cows.

Blood metabolites for PP and MP cows are presented in Table 5. Primiparous cows had greater ($P \leq 0.05$) serum concentrations of cholesterol (305 vs. 279 mg/dL), HDL cholesterol, BHBA, BUN, and ALP than MP cows. In contrast to the previous biomarkers, the TP and globulin were lower ($P \leq 0.01$) in PP than MP cows. There was a trend ($P = 0.10$) for greater concentration of TG in PP than MP cows. The concentrations of glucose, NEFA, albumin, AST, creatinine, and SAA were not affected by parity ($P > 0.10$).

Milk yield and composition, feed efficiency, body conformation parameters, and body fat thickness are presented in Table 6. Milk yield was approximately 6 kg/d lower ($P < 0.01$) in PP than MP cows. Also, the production of fat corrected milk, energy corrected milk and solid

corrected milk were lower ($P < 0.01$) in PP than MP cows. Similar to milk yield, protein and lactose yield were lower ($P \leq 0.01$) in PP than MP cows, whereas fat was not affected by parity ($P > 0.10$). The concentrations of protein, fat, and lactose in milk were greater ($P \leq 0.05$) in PP than MP cows, but fat to protein ratio was not affected by parity ($P > 0.10$).

The efficiency of milk yield per DMI was lower ($P < 0.01$) in PP than MP cows (Table 6). In contrast, when milk efficiency was calculated as fat corrected milk or energy corrected milk per DMI, the effect of parity was not significant ($P > 0.13$). Neither the change in BW nor body condition score was affected ($P > 0.28$) by parity, whereas the BFT tended ($P = 0.09$) to be lower in PP than in MP cows.

4. Discussion

The present study showed interesting observations about behavior, blood metabolites and efficiency of milk production in PP and MP cows fed a high concentrate diet. The animals and feeding conditions were relevant to current production conditions of modern dairy farms in Iran and to some extent in North America (Esmaeili, 2013; St-Pierre and Weiss, 2015).

Early post-feeding (i. g., daytime; < 6 h), the PP cows ate similar amounts of feed and sorted against long particles (i. g. between 8-19 mm), whereas during later times of day (i. g. at night) PP cows ate less feed and sorted in favor of long particles. Although such measurements have not been undertaken in comparison of PP and MP cows previously, this could be partly explained by no adaptation of PP cows to nighttime activity prior to lactation. Indeed, due to the recommended guidelines for feeding pregnant heifers before lactation (NRC, 2001) and no previous experience of lactation, PP cows had no previous experience of nighttime feeding. This pattern of animal activity putatively contributed to decreased feed intake at night and thus

prevented a positive observation of sorting activity against long particles at night, which has been previously observed (DeVries et al., 2011). However, lower DMI during night time possibly promoted greater daytime intake in PP compared with MP cows (< 6 h post morning feeding). The high DMI of PP cows during the morning along with no previous exposure to high-concentrate diets (Krause and Oetzel, 2006) could have resulted in a greater gut filling effect (Allen 2000). As result, the possibility of greater satiety during the day in PP cows could explain the decreased DMI at night (Allen, 2000). Because our cows were of mid-lactation status, it might be considered that they should be adapted to nighttime feeding, but a recent study has indicated that feeding behaviors may be sustained for more than a year (Miller-Cushon and DeVries, 2015). Moreover, it is possible the 14 days of adaptation to individual feeding might have been insufficient for the adaptation of nighttime feeding behaviors by PP cows.

It should be noted that both PP and MP cows had a rumen pH under 5.8 for ≥330 min per day. We conclude from these data that these cows were at least mildly acidotic (Zebeli et al., 2008), which was expected because of the high-concentrate diet. The dietary peNDF8 and peNDF1.18 corrected for sorting were 9.21 and 28.8 % for PP cows and 9.3 and 28.8 % for MP cows, respectively, which was not sufficient for the fiber requirements of either group (Zebeli et al., 2008).

Primiparous cows in the current study, despite lower intake and production, had greater concentrations of cholesterol, HDL, BHBA, and ALP activity as well as a trend to have greater TG in the blood. It seems the first lactation heifers that have not been exposed to high-concentrate diets until after calving (Penner et al., 2007) are not enough accustomed to manage and clear the metabolites loaded in the blood. Additionally, first lactation cows generally represent a largely unculled population (Oetzel, 2007; Humer et al, 2015). Thus, it is possible

that first lactation heifers with poorly regulated metabolism would be observed among PP cows, whereas such cows are more likely culled in later lactations. In contrast to the present study, others have failed to detect an effect of parity on metabolism (Cozzi et al., 2011; DeVries et al., 2011; Humer et al., 2015), which might be due to differences in diet formulation (level of concentrate) and milk production (< 35 kg/d).

Greater milk production in MP than PP cows was expected considering the greater DMI and mammary development. However, MP cows were more efficient in producing milk and numerically more efficient in producing 3.5% fat corrected milk. The growth requirement of PP cows could partially explain this observation, but such an improvement in milk production efficiency in MP compared with PP cows has not been documented previously (DeVries et al., 2011; Naderi et al., 2016). The lower feed efficiency in PP cows might be in part due to the greater level of cholesterol and TG despite lower milk production. We hypothesize that the metabolic expense of clearing these metabolites induced a stress condition in PP cows that affected the efficiency of milk production.

Overall, these results indicate that under conditions of our study (i. e. feeding a high concentrate diet), PP dairy cows showed different feeding behavior and presented altered concentrations of metabolites in plasma, which were possibly related to decreased feed efficiency. Because PP and MP cows are often housed separately on large dairy farms, a feeding strategy to promote nighttime activity could be beneficial.

Conflicts of interest

The authors declare that they have no competing interest.

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Table 1. Ingredient, chemical compositions, and particle size distribution of the diet

Item	Measurement
Ingredient, % of DM	
Corn silage	24.3
Alfalfa hay	10.9
Beet pulp	9.9
Barley grain, ground	12.7
Corn grain, ground	18.0
Soybean meal	11.6
Heat-treated soybean meal	3.3
Rice bran	2.5
Fish meal	1.5
Fat supplement	1.5
Trace mineral mix[1]	0.59
Vitamin mix[2]	0.39
Hydrogel[3]	0.31
Calcium carbonate	0.12
Dicalcium phosphate	0.10
NaCl	0.32
Sodium bicarbonate	0.88
Magnesium oxide	0.31
Nutrient composition,[4] % of DM	
DM	46.7

Ash	8.1
CP	15.1
NDF	33.5
Ether extract	4.2
NFC	39.1
Particle size distribution,[4] % of DM	
>19 mm	4.6
8-19 mm	25.0
1.18–8 mm	56.8
<1.18 mm	13.6
pef8	29.6
pef1.18	86.4
peNDF8	9.9
peNDF1.18	28.9

[1]Contained 800 mg/kg of Fe, 3000 mg/kg of Cu, 10000 mg/kg of Mn, 120 mg/kg of Co, 16000 mg/kg of Zn, 80 mg/kg of Se, 150 mg/ kg of I, 2000 mg/kg monensin.
[2]Contained 1300 kIU/kg of vitamin A, 360 kIU/kg of vitamin D, and 12 kIU/kg of vitamin E.
[3]Rumen buffer (Farzin Chemistry co., Isfahan, Iran)
[4]DM = dry matter; CP = crude protein; NDF = neutral detergent fiber; NFC = non-fiber carbohydrate
pef8 and pef1.18 = physical effectiveness factor determined as the DM proportion of particles retained on 2 sieves (19 and 8 mm) or 3 sieves (19, 8, 1.18 mm), respectively, of the PSPS (Lammers et al., 1996; Kononoff, 2002); peNDF8, peNDF1.18 = physically effective NDF calculated as dietary NDF content (% DM) multiplied by pef8 and pe1.18, respectively.

Table 2. Pattern of DMI by primiparous and multiparous lactating cows

Item	Primiparous	Multiparous	Pooled SEM	*P*-Value
Hours after morning feeding[1] (kg/h)				
0-2	2.80	2.97	0.096	0.17
2-4	0.88	1.07	0.075	0.08
4-6	1.14	0.93	0.055	0.01
6-24	0.74	0.88	0.021	<0.01
Total intake (kg/d)	22.4	25.1	0.53	<0.01

[1]Cows were fed at 10:00 A.M.

Table 3. Sorting index[1] for primiparous and multiparous lactating cows

Item	Primiparous	Multiparous	Pooled SEM	*P*-Value
0-6 h after morning feeding[2], %				
>19 mm	80.8	83.5	10.5	0.68
8-19 mm	92.2	94.7	2.53	0.02
1.18–8 mm	104.0	103.2	0.56	0.32
<1.18 mm	102.9	100.5	4.29	0.25
6-18 h after morning feeding, %				
>19 mm	74.4	75.4	9.82	0.86
8-19 mm	101.0	98.7	1.00	0.02
1.18–8 mm	102.5	102.7	1.21	0.87
<1.18 mm	102.4	104.8	0.74	0.03
Total (0-24 h), %				
>19 mm	66.7	72.3	8.81	0.40
8-19 mm	97.9	97.7	0.38	0.61
1.18–8 mm	102.9	102.6	0.66	0.66
<1.18 mm	102.2	102.6	1.36	0.57

[1]Calculated according to Leonardi and Armentano (2003)
[2]Cows were fed at 10:00 A.M.

Table 4. Rumen pH and VFA profile in primiparous and multiparous lactating cows

Item	Primiparous	Multiparous	Pooled SEM	P-Value
Rumenocentesis pH	5.91	5.91	0.06	0.95
Reticulorumen pH				
Mean	5.83	5.88	0.16	0.82
Max	6.48	6.67	0.09	0.19
Min	5.24	5.30	0.18	0.82
Duration pH <5.8, min/d	750	570	231	0.60
Duration pH <6.0, min/d	894	788	163	0.73
Total VFA, mM	103.5	98.3	2.77	0.19
VFA proportions, %				
Acetate (A)	50.3	50.8	0.37	0.31
Propionate (P)	23.2	23.5	0.53	0.63
Butyrate	21.8	21.1	0.33	0.08
Isovalerate	1.69	1.58	0.25	0.43
Valerate	2.92	3.03	0.09	0.34
A/P	2.20	2.20	0.055	0.95

Table 5. Blood metabolites in primiparous and multiparous lactating cows

Item[1]	Primiparous	Multiparous	Pooled SEM	P-Value
Glucose, mg/dL	60.4	59.4	1.15	0.21
Cholesterol, mg/dL	305	279	8.2	0.03
HDL chol, mg/dL	76.7	71.0	3.34	0.05
TG[2], mg/dL	1.13	1.11	0.012	0.10
NEFA, mmol/L	0.35	0.38	0.057	0.41
BHBA, mmol/L	0.73	0.63	0.066	0.02
BUN, mg/dL	13.7	12.4	0.85	<0.01
TP, g/dL	7.90	8.32	0.095	<0.01
Albumin, g/dL	3.87	3.87	0.043	0.97
Globulin, g/dL	4.03	4.41	0.09	0.01
AST, U/L	63.9	66.0	3.52	0.68
ALP, U/L	127.5	93.5	6.25	<0.01
Creatinine, mg/dL	1.00	0.97	0.04	0.28
SAA, mg/L	20.3	24.3	1.95	0.22

[1]HDL = high density lipoprotein; TG = triglyceride; NEFA = non-esterified fatty acids; BHBA = beta-hydroxy butyric; BUN = blood urea nitrogen; TP = total protein; AST = aspartate aminotransferase; ALP = alkaline phosphatase; SAA = serum amyloid A.
[2]The data were log transformed to achieve a normal distribution.

Table 6. Milk production, tissue gain, and feed efficiency in primiparous and multiparous lactating cows

Item	Primiparous	Multiparous	Pooled SEM	P-Value
Yield, kg/d				
Milk	42.9	49.3	1.17	<0.01
3.5% FCM[1]	32.3	36.5	1.59	<0.01
ECM[2]	35.9	40.3	1.41	<0.01
SCM[3]	30.6	33.8	1.27	0.01
Fat yield, kg/d	1.07	1.14	0.095	0.26
Protein yield, kg/d	1.19	1.35	0.036	<0.01
Lactose yield, kg/d	2.02	2.25	0.055	0.01
Composition, %				
Fat	2.53	2.25	0.16	0.01
Protein	2.83	2.75	0.09	0.05
Lactose	4.69	4.56	0.03	<0.01
Fat:protein	0.90	0.84	0.083	0.11
Feed efficiency				
Milk yield/DMI[4]	1.88	2.03	0.032	<0.01
FCM/DMI	1.45	1.49	0.053	0.13
ECM/DMI	1.61	1.65	0.046	0.16
BW[5] changes, kg	17.9	13.9	3.74	0.28
BCS[4]	3.11	3.15	0.055	0.55
BFT,[5] mm	28.9	30.8	2.05	0.09

[1]3.5% FCM, kg/d = 0.432 milk yield, kg/d + 13.23 fat yield, kg/d (Gaines, 1928)
[2]ECM, kg/d = 0.3246 milk yield, kg/d + 12.96 fat yield, kg/d + 7.04 protein yield, kg/d (Jenkins et al., 1998)
[3]SCM, kg/d = 12.3 fat yield, kg/d + 6.56 solid not fat yield, kg/d - 0.0752 milk yield, kg/d (Tyrrell and Reid, 1965)
[4]DMI = dry mater intake
[5]BW= body weight
[6]BCS = Body condition score was determined using five-scale method where 1 = emaciated and 5 = obese (Ferguson et al., 1994).
[7]BFT = Back fat thickness was measured using ultrasonographic method (Schroder and Staufenbiel, 2006).

Highlights

- Primiparous (PP) and multiparous (MP) dairy cows were fed high-concentrate diets.
- The data on performance, feeding behaviors, and blood metabolites were measured.
- Acidosis and metabolic stress were developed for both PP and MP cows.
- The level of blood metabolites was higher for PP cows in spite of lower intake and production.

- The feed efficiency of PP cows was lower than MP cows.