J. Dairy Sci. 89:3439–3446

Increasing Milking Intervals Decreases the Mammary Blood Flow and Mammary Uptake of Nutrients in Dairy Cows

E. Delamaire and J. Guinard-Flament[1]
Unité Mixte de Recherches, Institut National de la Recherche Agronomique (INRA)–Agrocampus Rennes Production du Lait, 33590 Saint-Gilles, France

ABSTRACT

Increasing the milking intervals reduces milk yield. The aims of this study were to determine whether the reduction in milk yield could be explained by a decrease in mammary uptake of the nutrients or a decrease in the efficiency of the mammary gland in using the milk precursors to synthesize milk components, or both. In a Latin square design with 5 periods, 4 multiparous lactating dairy cows in midlactation were milked at 8-, 12-, 16-, or 24-h intervals over a period of 7 d. The cows were surgically prepared to estimate the net mammary balance of nutrient precursors of milk components (glucose, α-amino nitrogen, acetate, β-hydroxybutyrate, and total glycerol). The efficiency of the mammary gland in synthesizing milk components was estimated by the mammary uptake:milk output ratio. After 7 d of treatment, the decrease in milk yield of 6.1 kg/d between 8- and 24-h milking intervals was associated with a reduction in the uptake of nutrients by the mammary gland, whereas the efficiency of the mammary gland in synthesizing milk components remained relatively unchanged. The mammary uptake decreased by 26% for glucose, 32% for α-amino nitrogen, 18% for acetate, 24% for total glycerol, and 24% for β-hydroxybutyrate, respectively. These reductions in nutrient uptake were due to a decrease in the mammary blood flow (1.23 ± 0.24 L/min). For milk fat precursors (acetate, β-hydroxybutyrate, and total glycerol), the decrease in mammary blood flow explained the entire reduction in the mammary uptake. For glucose and the milk protein precursors, the reduction in the mammary blood flow explained 60% of the decrease in the mammary uptake, with the other 40% being accounted for by a reduction in the mammary extraction of nutrients. The nutrient uptake was altered as milk yield decreased. These decreases began with the 16-h milking interval and were higher at the 24-h milking interval.

Key words: dairy cow, milking frequency, mammary blood flow, mammary nutrient uptake

INTRODUCTION

Decreasing the milking frequency reduces milk yield (Davis et al., 1999; Rémond and Pomiès, 2004), which could be linked to a decline in the mammary uptake of nutrients associated with a change in the efficiency of the mammary gland in converting these nutrients into milk components. Indeed, Fleet and Peaker (1978) reported a reduction in the mammary uptake of glucose, acetate, and oxygen 2 d after cessation of milking in the goat. A decrease in the mammary nutrient uptake could be due to a decrease in the mammary blood flow (**MBF**) or a decrease in ability of the gland to extract nutrients from the blood compartment, or both. Previously, we showed that the extraction ability of the mammary gland could be affected in the dairy cow following an increase in the milking interval from 8 to 24 h (Delamaire and Guinard-Flament, 2006). Milk volume fell by 25% and the extraction rates of milk component precursors (glucose, α-amino nitrogen, BHBA, and total glycerol) declined from 32 to 27% between 8- and 24-h milking intervals. Other studies have suggested that a reduction in MBF may also occur. In cows milked once daily for 7 d, Guinard-Flament and Rulquin (2001) observed a 28% decline in milk yield and a 10% reduction in the MBF. In the goat, a lengthening of the interval between milkings from 26 to 36 h caused a 50% reduction in the MBF (Stelwagen et al., 1994; Farr et al., 2000). On the other hand, the effects of changing to a milking frequency of more than twice daily are less clear. In goats milked 5 times in 12 h, milk secretion increased by 24% and the MBF increased by 44% (Prosser and Davis, 1992). However, in goats milked hourly for 8 h, milk secretion increased by 15%, but there was no change in the MBF (Maltz et al., 1984).

The aim of the present study was to determine whether the reduction in milk yield observed in response to a reduced milking frequency was associated with a reduction in the mammary uptake of nutrients, partly due to a reduction in the MBF or in the efficiency of the mammary gland to convert the plasma nutrients into milk components, or both. This study established dose–response curves for the mammary utilization of nutrients as a function of increasing the milking interval from 8 to 24 h with a constant nutrient intake.

Received January 27, 2006.
Accepted April 7, 2006.
[1]Corresponding author: Jocelyne.Flament@agrocampus-rennes.fr

MATERIALS AND METHODS

Treatments, Cows, and Experimental Design

Treatments, cows, and sample analyses were as described previously by Delamaire and Guinard-Flament (2006). Treatments consisted of 4 milking frequencies under a constant level of feeding: milking 3 times daily, milking twice daily, milking 3 times in 2 d, and milking once daily, which corresponded to 8-, 12-, 16-, and 24-h milking intervals, respectively.

Four multiparous Holstein cows (635 ± 30 kg of BW) in their second or third lactation at 72 ± 3 d postpartum at the start of the experiment were used. The cows were surgically prepared to estimate the net mammary balance of nutrients in the left-half udder, according to the method described by Guinard et al. (1994). One month before the beginning of the experiment, 2 permanent catheters were inserted into the left carotid and subcutaneous vein. An ultrasonic flow probe (Probe 20 S, i.d. 20 mm, cable length 2.5 m; Transonic Systems Inc., Ithaca, NY) was implanted around the left external pudic artery, before the S-shaped bend in the artery, to measure the MBF. The flow probe cable was protected with Silastic tubing (Silclear medical grade silicone tubing, i.d. 3 mm, o.d. 6 mm; VWR International SAS, Briare, France). Two rings of Dacron (Mersutures, TS53; Ethicon, Issy-Les-Moulineaux, France) were placed along the cable and at the level of exteriorization to prevent any spread of infection.

The experiment was conducted using a Latin square design with 4 cows and 5 periods. The duration of each period was 2 wk. The first week provided a transition when cows were milked twice daily (0630 and 1830 h). The second week was the experimental week, with cows milked according to the treatments allocated. A fifth period was subsequently added because one ultrasonic flow probe stopped emitting a signal during the first period; this cow was eliminated. During the third period, one cow experienced digestive problems. Hence, during the fifth period, this cow received the treatment planned for the third period. Two other cows were subjected to the 2 extreme treatments, i.e., milking once and 3 times daily. Consequently, the results are for 3 cows.

Measurements, Sampling, and Analyses

MBF. The MBF was continuously measured throughout the experimental period. The sampling rate of the 2 flow meters (T208D; Transonic Systems Inc.) was fixed at 200 Hz. The MBF and heart rate were averaged every minute and recorded using IOX software (EMKA Technologies, Paris, France). The cows were fitted with a sensor to record their position (standing, lying). Because MBF varies according to the position of the animal, the MBF and animal position were recorded simultaneously to study the variations in the MBF as a function of the position.

Blood. Analyses were performed as described previously (Delamaire and Guinard-Flament, 2006). Briefly, concurrently with MBF recording, 12 blood samples were collected simultaneously, during the last 24 h of the period, from the artery and vein using heparinized syringes (S-Monovette, 7.5 mL; Sarstedt, Nümbrecht, Germany). Samples were pooled by cow and period. The concentrations of glucose (precursor of lactose), α-amino nitrogen, and AA (precursors of milk proteins), acetate, BHBA, NEFA, and total glycerol (precursors of milk fat) were determined from the arterial and venous plasma to analyze the mammary use of blood nutrients. Heparinized plasma was used to determine the levels of glucose, α-amino N, BHBA, total glycerol, and NEFA, and deproteinized plasma was used to determine the levels of acetate. Plasma was acidified with 50% sulfosalicylic acid (vol/vol), centrifuged at 3,000 $\times g$ for 5 min at 4°C, and then diluted in a buffer solution (vol/vol) to analyze AA concentrations. Samples were pooled by cow and period and analyzed according to the methods described by Moore and Stein (1954) using chromatography on a cation-exchange resin column with a Biotronick LC3000 autoanalyser (Biotronick, Maintal, Germany), and were quantified by reaction with ninhydrin. Oxygen and carbon dioxide concentrations were determined by a gas analyzer (ABL 625, Radiometer Copenhagen, Brønshøj, Denmark) from blood samples collected using special "blood gas" heparinized syringes (S-Monovette, 2 mL, Sarstedt; Nümbrecht, Germany.

Milk. During the 7 d of treatment, the cows were milked by each half gland. The milk yield was recorded, and the fat and protein contents were determined by infrared analysis (MilkoScan; Foss Electric, Hillerød, Denmark). After 7 d of treatment, the milk lactose and milk fatty acid levels were analyzed as previously described (Delamaire and Guinard-Flament, 2006).

Calculations and Statistical Analyses

The results are given for 3 cows (n = 14). Data concerning milk performance, the MBF, and the net mammary balance of nutrients are given after 7 d of treatment.

The arterial flow is equal to the arterial concentration × mammary plasma flow. The mammary plasma flow is calculated from the MBF (mean of the whole day) corrected for arterial hematocrit values. The mammary uptake is equal to the mammary plasma flow × arteriovenous difference except for oxygen and carbon dioxide