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Feed and nitrogen efficiency are affected differently but milk lactose production is stimulated equally when isoenergetic protein and fat is supplemented in lactating dairy cow diets

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ABSTRACT

Fifty-six Holstein-Friesian cows were used in a randomized complete block design to test the effects of supplemental energy from protein (PT) and fat (FT) on lactation performance and nutrient digestibility in a 2 × 2 factorial arrangement. During the control period, cows were adapted for 28 d to a basal total mixed ration consisting of 34% grass silage, 33% corn silage, 5% grass hay, and 28% concentrate on a dry matter (DM) basis. Experimental rations were fed for 28 d immediately following the control period and consisted of (1) low protein, low fat (LP/LF), (2) high protein, low fat (HP/LF), (3) low protein, high fat (LP/HF), or (4) high protein and high fat (HP/HF). To obtain the HP and HF diets, intake of the basal ration was restricted and supplemented isoenergetically (net energy basis) with 2.0 kg/d of rumen-protected protein (soybean + rapeseed, 50:50 mixture on DM basis) and 0.68 kg/d of hydrogenated palm fatty acids (FA) on a DM basis. Milk production and composition, nutrient intake, and apparent digestibility were measured during the final 7 d of the control and experimental periods. No interaction was found between PT and FT on milk production and composition. Yields of milk, fat- and protein-corrected milk, and lactose increased in response to PT and FT and lactose concentration was unaffected by treatment. Milk protein concentration and yield increased in response to PT, and protein yield tended to increase in response to FT. Milk fat concentration and yield increased in response to FT and were unaffected by PT. Milk urea concentration increased and nitrogen efficiency decreased in response to PT. Feed and nitrogen efficiency were highest on the LP/HF diet and both parameters increased in response to FT, whereas milk urea concentration was not affected by FT. Energy from fat increased the concentration and yield of ≥16-carbon FA in milk and decreased the concentration of FA synthesized de novo, but had no effect on their yield. Concentration and yield of de novo-synthesized FA increased in response to PT. Concentration and yield of polyunsaturated FA increased and decreased in response to PT and FT, respectively. Apparent total-tract digestibility of crude fat decreased in response to PT, and FT increased crude protein digestibility. Energy supplementation through rumen-inert hydrogenated palm FA appears to be an efficient feeding strategy to stimulate milk production with regard to feed and nitrogen efficiency compared with supplementing an isoenergetic level of rumen-protected protein.
Key words: rumen-protected protein, hydrogenated palm fatty acid, milk lactose, digestibility

INTRODUCTION

Rising demand for sustainably produced milk protein products (OECD/FAO, 2015) emphasizes the importance of understanding how energy-yielding feedstuffs affect efficient synthesis of milk and its components. Several studies compare the effects of glucogenic substrates with lipogenic substrates (Grum et al., 1996; van Knegsel et al., 2007; Boerman et al., 2015), but comparisons between isoenergetic supplements of aminogenic and lipogenic nutrients are scarce. It is well established that protein degradation in the rumen increases with dietary CP content. If available protein in the rumen exceeds microbial needs, or if availability of AA exceeds postabsorptive requirements, excess NH_3 is produced and excreted as urea (Colmenero and Broderick, 2006; Dijkstra et al., 2013). Energy is required to process and excrete a surplus of N, which increases heat production and decreases retained energy and milk energy (Reed et al., 2017). As an alternative to

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feeding high-CP diets, balancing rations to supply sufficient levels of EAA in support of milk protein synthesis has been shown to improve postabsorptive N efficiency and increase milk protein yield (Haque et al., 2012; Lee et al., 2012; Arriola Apelo et al., 2014). Thus, great focus has been placed on maximizing dietary protein utilization by increasing post-ruminal supply of EAA and energy precursors through rumen-protected (**RP**) products.

Lactose is the main osmotic driver of total milk yield; therefore, the glucogenic capacity of a dietary ingredient can have a profound effect on lactation performance. Glucose supply to the mammary gland can be increased through absorption of glucogenic nutrients and flux through hepatic gluconeogenesis. Ideally, the majority of dietary AA would be used by the mammary gland for milk protein synthesis at first pass, but AA will be used for gluconeogenesis when concomitant supply of glucogenic energy is limiting for productive purposes. The corollary is that, by supplying rapidly available energy precursors, a larger proportion of dietary AA can be used for milk protein synthesis (Rius et al., 2010a,b). However, lactation responses to supplemental glucose availability are not always positive and depend on the nutritional status and production potential of the animal (Cant et al., 2002; Nichols et al., 2016). Saturated fat is energy dense and included in lactating cow diets as a source of nonfermentable energy. Saturated long-chain fatty acids (**LCFA**) are supplemented into dairy rations with the goal of increasing milk production while minimizing inhibitory effects on functional digestibility (Jenkins, 1993). In contrast, supplementation with UFA has been associated with perturbed DMI, altered ruminal biohydrogenation and microbial activity, and depressed milk fat synthesis (Allen, 2000; Baumgard et al., 2001). Saturated LCFA have the potential to provide high amounts of gross energy to the animal, but on a net basis do not directly contribute to glucose precursors necessary for lactose synthesis by the mammary gland. The apparent effect of supplemental fat on DMI and digestibility leads to variation in cow performance across studies (Rabiee et al., 2012). If DMI is not severely decreased and digestibility remains unaffected, the high energy density of rumen-inert fat supplements increases ME consumption and may improve energetic efficiency through the direct transfer of FA into milk (Hammon et al., 2008; Boerman et al., 2015).

The interaction between AA and glucose or glucose precursors on milk production has been examined in several studies (Raggio et al., 2006; Lemosquet et al., 2009; Nichols et al., 2016). Furthermore, many studies compare the effects of glucogenic or lipogenic nutrients through forage substitution in the diet (Cantalapiedra-Hijar et al., 2014; Boerman et al., 2015; Piantoni et al., 2015) or abomasal infusion (Oldick et al., 1997), but the interaction between protein and fat supplementation has not been extensively investigated. We expected that, at isoenergetic levels, the inherent properties of aminogenic versus lipogenic energy would differently affect whole-body metabolism, which may be reflected in milk production responses. Supplemental protein may yield AA and stimulate protein synthesis in both the mammary gland and extramammary tissues, but as a glucogenic substrate, AA may yield glucose potentially in support of lactose synthesis. In contrast, fat supplementation provides FA that may contribute to milk fat yield but do not directly yield substrates to increase milk protein or lactose synthesis. However, this may be achieved if intramammary glucose is spared through a reduction in de novo FA synthesis. Thus, our objective was to characterize the independent and interactive effects of isoenergetic protein and fat supplementation on milk production and composition and nutrient digestibility, where changes to the energy content of treatment diets were accomplished by supplementation with RP protein and rumen-inert fat.

MATERIALS AND METHODS

Experimental Design and Treatment Diets

All experimental procedures were approved by the Animal Care and Use Committee for Nutreco Nederland B.V. (Amersfoort, the Netherlands) and conducted under the Dutch Law on Animal Experiments. Fifty-six Holstein-Friesian dairy cows (167 ± 87 DIM; 2.8 ± 1.9 lactations; 20 primiparous, 36 multiparous) were used in a randomized complete block design where two 28-d feeding periods (control and experimental) consisted of 21 d of diet adaptation and 7 d of data collection. Supplemental energy from protein (**PT**) or fat (**FT**) was tested in a factorial arrangement. During the control period, cows were fed a basal diet as a TMR meeting NE_L and MP requirements consisting of 34% grass silage, 33% corn silage, 5% grass hay, and 28% concentrate on a DM basis. Cows were blocked by parity, DIM, and DMI of the final 7 d of the control period. Within blocks, cows were randomly assigned to 1 of 4 diets for the experimental period: (1) low protein, low fat (**LP/LF**; 95% MP, 95% NE_L), (2) high protein, low fat (**HP/LF**; 131% MP, 107% NE_L), (3) low protein, high fat (**LP/HF**; 95% MP, 107% NE_L), or (4) high protein and high fat (**HP/HF**; 131% MP, 119% NE_L), where MP and NE_L are expressed relative to animal requirements in the control period. For all treatments, basal diet intake for individual cows was restricted to 95% of their ad libitum intake recorded