J. Dairy Sci. 93:2508–2516
doi:10.3168/jds.2009-2876

Lipomobilization in periparturient dairy cows influences the composition of plasma nonesterified fatty acids and leukocyte phospholipid fatty acids

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ABSTRACT

The periparturient period is characterized by sudden changes in metabolic and immune cell functions that predispose dairy cows to increased incidence of disease. Metabolic changes include alterations in the energy balance that lead to increased lipomobilization with consequent elevation of plasma nonesterified fatty acids (NEFA) concentrations. The objective of this study was to establish the influence of lipomobilization on fatty acid profiles within plasma lipid fractions and leukocyte phospholipid composition. Blood samples from 10 dairy cows were collected at 14 and 7 d before due date, at calving, and at 7, 14, and 30 d after calving. Total lipids and lipid fractions were extracted from plasma and peripheral blood mononuclear cells. The degree of lipomobilization was characterized by measurement of plasma NEFA concentrations. The fatty acid profile of plasma NEFA, plasma phospholipids, and leukocyte phospholipids differed from the composition of total lipids in plasma, where linoleic acid was the most common fatty acid. Around parturition and during early lactation, the proportion of palmitic acid significantly increased in the plasma NEFA and phospholipid fractions with a concomitant increase in the phospholipid fatty acid profile of leukocytes. In contrast, the phospholipid fraction of long-chain polyunsaturated fatty acids in leukocytes was diminished during the periparturient period, especially during the first 2 wk following parturition. This study showed that the composition of total plasma lipids does not necessarily reflect the NEFA and phospholipid fractions in periparturient dairy cows. These findings are significant because it is the plasma phospholipid fraction that contributes to fatty acid composition of membrane phospholipids. Increased availability of certain saturated fatty acids in the NEFA phospholipid fractions may contribute to altered leukocyte functions during the periparturient period.

Key words: nonesterified fatty acids, peripheral blood mononuclear cells, periparturient, lipomobilization

INTRODUCTION

The onset of lactation imposes vast energy demands on the dairy cow, involving considerable changes in both dietary requirements and metabolic functions. In dairy cows, the energy requirements of early lactation are generally not met by the diet, and mobilization of tissue energy reserves is required. Mobilization of lipids from tissue stores involves the release of fatty acids into the blood stream. Fatty acids are transported in circulation by various lipid fractions that include neutral lipids (**NL**), phospholipids (**PL**), and NEFA. The NL fraction is composed of triglycerides, diglycerides, monoglycerides, and cholesteryl esters. Both NL and PL are carried by lipoproteins including very low density lipoprotein, low density lipoprotein, and high density lipoprotein that function to maintain the lipids in aqueous solution. Fatty acids from these molecules are made available to cell metabolism by the action of lipoprotein lipases (Tall, 1995). In contrast, NEFA are held in solution in combination with albumin, although a small portion of NEFA is transported as unbound monomers in aqueous solution (Richieri and Kleinfeld, 1995). Circulating NEFA are readily available for complete oxidation by a variety of tissues. However, a large portion of them is either partially oxidized to ketone bodies or re-esterified to form triglycerides in the liver (Grummer, 1993; Hocquette and Bauchart, 1999).

In humans, the fatty acid profiles of plasma lipid fractions and erythrocyte cellular membranes vary greatly during the last trimester of gestation through the first weeks of lactation (Al et al., 1995; Otto et al., 2001). These shifts are a consequence of elevated requirements for fatty acids by the growing fetus and mammary gland (Al et al., 1995; Otto et al., 2001; Hanebutt et al., 2008). Similarly, dairy cows experience a sharp increase in concentrations of lipids in plasma during the periparturient period in response to higher metabolic demands driven by fetal needs and the onset of lactation (Drackley, 1999). This characteristic was described quantitatively for the NEFA fraction. Plasma NEFA in

Received November 2, 2009.
Accepted March 1, 2010.
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late lactation and the dry period average less than 0.2 m*M*/L. Concentrations start to increase 2 wk before parturition reaching the highest point during the first 10 d of lactation with concentrations of approximately 0.750 m*M*/L depending on the degree of lipomobilization. Concentrations may surpass 1.0 m*M*/L, especially in cows that are destined to develop ketosis (Adewuyi et al., 2005). These alterations in serum lipids have consequences not only for energy redistribution but also for cell metabolism and function.

Disturbances in adipose tissue function and lipid homeostasis (lipodystrophies and dyslipidemias) in human and animal models can lead to insulin resistance and metabolic disorders including altered cellular immune status (Montecucco and Mach, 2009). Fatty acids can affect cellular immune function by modifying intracellular signaling, associating with lipid-raft proteins, binding to specific toll-like receptors, controlling gene expression, activating transcription factors, inducing apoptosis, and modifying lipid mediator production (Calder and Yaqoob, 2007). Therefore, the fatty acid composition of immune cells directly affects their activity. The effect of specific fatty acids on immune cell function was described in humans (Håversen et al., 2009). However, changes in the fatty acid profile of the plasma NEFA and PL fractions during the periparturient period of dairy cows are not well defined in the literature. Furthermore, the implications of shifts in the fatty acid composition of bovine immune cell lipid fractions are largely unknown. The objective of this study was to describe the variations in the fatty acid profile of NEFA, plasma PL fractions, and PL content of peripheral blood mononuclear cells (**PBMC**) obtained from periparturient dairy cows.

MATERIALS AND METHODS

Animals and Diets

All animal procedures were approved by the Michigan State University Animal Care and Use Committee. Ten healthy, mature, multiparous Holstein cows were selected at the moment of dry-off from a large, commercial Michigan dairy herd. Animals were chosen based on the following criteria: >210 d of gestation, a last DHI test with SCC <250,000 cells/mL, and a BCS of 3.5 to 3.75. During the trial, cows were monitored for health status and exhibited no lameness or other disease. Animals were housed in freestalls and fed 2 different rations based on lactation status—a transition diet and a lactation diet. The ration composition and fatty acid profile of each diet is shown in Tables 1 and 2. Samples were collected when dry cows entered the close-up pen at 14 d before expected calving, 1 wk later at 7 d before due date, at calving, and at 7, 14, and 30 d after calving.

Isolation of PBMC

Samples were collected in the morning between 0800 and 0900 h after feed was delivered. Blood (150 mL) was obtained by jugular venipuncture and immediately

Table 1. Ingredient composition (kg of DM, unless otherwise noted) of precalving and lactation diets

	Diet	
Item	Transition	Lactation
Ingredient		
Alfalfa haylage[1]	0	6.52
Corn silage[2]	14.27	23.53
Wheat straw	4.24	0.46
Wet corn gluten	1.23	1.14
Dry corn gluten	0	1.28
Bakery by-product	0	1.23
Canola meal	0	1.00
Corn grain, medium grind	0	1.78
Soybean meal, solvent	0	2.01
Dried citrus pulp	0	1.28
Wet beet pulp	0	3.97
High moisture corn	0	2.22
Supplements and mineral mix	0.55	1.60
Vitamin ADE mix[3]	0.04	0.02
Trace mineral mix[4]	0	0.02
Selenium blend[5]	0.05	0
Vitamin E[6]	0.005	0
Sodium selenate	0.003	0
Sodium sesquicarbonate	0	0.52
Calcium carbonate	0.134	0.47
Sodium chloride	0.078	0.26
Ground soybean hulls	0.096	0
Wheat middlings	0	1.2
Magnesium sulfate	0.187	0
Calcium sulfate	0.311	0
Magnesium oxide	0.062	0.067
Blood meal	0.187	0.552
Fishmeal	0.062	0.247
Biotin 1%	0.005	0.004
Mepron[7]	0	0.01
Tallow	0.024	0.1
Rumensin 80[8]	0.004	0.003
Chemical analysis, % of DM		
NDF	50.9	29.2
ADF	29.9	16.89
Ether extract	3.08	3.9
NE_L, MJ/kg of DM	5.49	7.27

[1]Alfalfa haylage 42% DM (as fed).

[2]Corn silage 31% DM (as fed).

[3]Vitamin ADE mixture contained (g/kg) 10.8 retinyl acetate, 0.18 cholecalciferol, and 0.047 DL-α-tocopherol.

[4]Trace mineral mix contained (g/100 g): 13.0 calcium, 0.3 magnesium, 2.0 copper, 8.8 magnesium, 12.0 sulfur, 10.5 zinc, 0.3 manganese, 0.25 cobalt, and 0.19 iodine.

[5]Selenium blend contains 0.006% sodium selenite.

[6]Vitamin E contained 68.0 g/kg of DL-α-tocopherol.

[7]Rumen-protected methionine; Evonik Industries AG, Essen, Germany.

[8]Elanco Animal Health, Greenfield, IN.