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Animal Reproduction Science 108 (2008) 98–106

ANIMAL REPRODUCTION SCIENCE

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Influence of oxidative stress and metabolic adaptation on PON1 activity and MDA level in transition dairy cows

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Received 10 May 2007; received in revised form 16 July 2007; accepted 23 July 2007
Available online 6 August 2007

Abstract

Serum PON1 is a HDL-associated enzyme that protects lipoproteins, both LDL and HDL, against oxidation and it is considered as an antioxidative/anti-inflammatory component of HDL. Dairy cows are highly susceptible to oxidative stress which commonly occurs in late pregnancy and early lactation. During the transition period, increased production of reactive oxygen species is associated to processes of metabolic adaptation to a low-energy balance. We investigated serum paraoxonase-1 (PON1) activity and malondialdehyde (MDA) concentration to assess the antioxidative/prooxidative status during pregnancy and the postpartum period. In order to evaluate metabolic homeostasis, common metabolic parameters (glucose, triglyceride, total cholesterol, HDL-C and albumin concentrations) were determined as well. A significantly lower PON1 activity was found in late pregnancy and early postpartum ($P < 0.05$) compared to the first and the second trimester of pregnancy and the mid-lactation. MDA level was significantly higher ($P < 0.05$) in the dry period compared to pregnant lactating and postpartum cows. Serum glucose concentration ($P < 0.001$) was lower in the early and late puerperium indicating low-energy balance in the early lactation. Serum triglyceride and albumin concentrations were lower in late puerperium ($P < 0.001$), while total cholesterol

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0378-4320/$ – see front matter
doi:10.1016/j.anireprosci.2007.07.012

and HDL-C were lower during the dry period ($P < 0.05$) as well as in early postpartum ($P < 0.001$). Significant correlations of PON1 activity with glucose ($P < 0.05$), albumin ($P < 0.05$), total cholesterol ($P < 0.001$) and HDL-C ($P < 0.001$) were also found. The observed lower serum PON1 activity and higher MDA level in late pregnancy and early postpartum could indicate a prooxidants/antioxidants imbalance influenced by reproductive stress and metabolic adaptation in the transition period of dairy cows.

Keywords: Dairy cows; Transition period; Oxidative stress; Metabolic disorders; Paraoxonase; Malondialdehyde

1. Introduction

Paraoxonase-1 (PON1; E.C. 3.1.8.1) is a mammalian enzyme synthesized primarily in the liver and secreted into the blood (Hassett et al., 1991). In bovine and human serum, PON1 is associated with HDL particles (Sorenson et al., 1999; Miyamoto et al., 2005). In the 1950s the enzyme was recognized to have a role in the metabolism of xenobiotics (Aldridge, 1953). It can hydrolyze the toxic oxon metabolites of organophosphorus compounds providing limited protection against chronic exposure to organophosphates (Draganov and La Du, 2004). Mackness (1989a,b) has shown that PON1 plays an important physiological role in lipid metabolism. PON1 can hydrolyze oxidized lipids in a form of lipid hydroperoxides generated on lipoproteins (both HDL and LDL) and protect against the development of oxidative stress (Mackness et al., 1991a, 1993). A decreased serum PON1 activity in humans has been well established in metabolic diseases associated with atherosclerosis (Mackness et al., 1991b, 2001, 2002). Ferre et al. (2006) showed a decrease in PON1 activity in chronic liver diseases. We have previously shown lower PON1 activity in dairy cows during late pregnancy and early lactation as well as in cows with liver hypertrophy (Turk et al., 2004, 2005a,b) most probably as a consequence of oxidative stress and metabolic disturbance accompanied with overall reduction in protein synthesis mainly proceeded in liver. Recently, Bionaz et al. (2007) also found lower PON1 activity in transition dairy cows and they suggested the influence of inflammatory conditions in the reduction of PON1 activity.

Transition period in dairy cows presents a risk interval for metabolic disorders. An increased capability of milk production is associated with the changes of metabolic and energy homeostasis (Butler, 2000; Lucy, 2003). A dramatic increase in energy requirements during late pregnancy and early lactation makes dairy cows highly susceptible to negative energy balance (NEB) which commonly occurs in the transition period. The metabolic adaptation to NEB requires interactions of metabolic fuels and its failure may occur in various tissues like the liver, adipose tissue and others (Herdt, 2000). Intensified processes of NEFA oxidation proceeded in the liver, result in the increased production of reactive oxygen species (ROS) and oxidative stress development (Mudron et al., 1999). Thus, metabolic profiles as well as antioxidative/prooxidative status are a useful tool for monitoring health and reproduction status in cows during the transition period.

The objective of this study was to assess the antioxidative/prooxidative status by measuring the paraoxonase-1 (PON1) activity and malondialdehyde (MDA) concentration. MDA is one of the most frequently used indicators of lipid peroxidation. The common metabolic parameters, i.e. glucose, triglyceride, total cholesterol, HDL-cholesterol (HDL-C) and albumin concentrations were also determined to assess metabolic homeostasis of cows. The PON1/HDL ratio was calculated as well, taking into account that most of PON1 molecules in the blood are bound to HDL particles.