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Effects of vanadium supplementation on performance and metabolic parameters in periparturient dairy cows

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ABSTRACT

Thirty-two multiparous Holstein cows were used from 4 week prior to calving through 4 week postpartum to investigate the effects of vanadium (V) supplementation on performance, production, and metabolic parameters. In a complete randomized block design set-up, after 1-week of an adaptation period, cows were assigned randomly to receive 1 of 4 V levels: 0, 0.04, 0.08, and 0.12 mg of V as vanadyl sulfate/kg of $BW^{0.75}$. Performance parameters (BW, BCS, DMI, and energy balance) did not change by V supplementation. While there was no alterations in concentrations of milk component, milk yield increased quadraticaly as supplemental V level increased ($P = 0.04$). During neither the prepartum period nor the postpartum period, plasma insulin concentration was affected by the treatments. However, plasma glucose concentration increased and plasma NEFA concentration decreased in a quadratic fashion in response to increasing supplemental V level ($P < 0.05$). During early lactation, but not during late gestation, the insulin: glucose ratio decreased quadraticaly ($P = 0.04$). In conclusion, V may play a role in modulation of the action of insulin and metabolic biomarkers related to energy metabolism during the periparturient period.
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1. Introduction

Concepts of metabolic adaptation during the periparturient period (Bauman and Currie, 1980; Bell and Bauman, 1997; Drackley, 1999) are linked postpartum health status and productivity. The nutritional management strategies during the transition period are aimed to ease metabolic transition (Grummer, 1993, 1998). One of the major alterations in the periparturient dairy cow is to be unable to keep pace with homeorhetic adaptation, namely providing sufficient glucose production to be utilized by adipose tissue and muscle. These are associated with reduced tissues sensitivity and responsiveness to insulin (Bell, 1995; Bell and Bauman, 1997), leading to high incidence of metabolic disorder in dairy cow. Therefore, any approach that can improve glucose production and availability and that can suppress lipolysis to improve insulin sensitivity

Abbreviations: ADF, acid detergent fibre; BCS, body condition score; BHBA, beta-hydroxybutyrate; BW, body weight; CP, crude protein; DM, dry matter; DMI, dry matter intake; NEB, negative energy balance; NEFA, non esterified fatty acid; NDF, neutral detergent fibre; NFC, non fibre carbohydrate; OM, organic matter; SNF, solid not fat; TMR, totally mixed ration.

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and enhance response to insulin may have significant production and health responses during the periparturient period (Grummer, 1993).

Vanadium (V) is a group 5 transition element that exists in several valence states (-3, −1, 0, and +1 to +5). Under physiological conditions, V is found in either an anionic form (vanadate) or a cationic form (vanadyl) (Brichard and Henquin, 1995). Its pentavalent form is toxic for animals and humans (Domingo et al., 1995). Cationic form is 6–10 times more toxic than anionic form (Poucheret et al., 1998). However, during the last decades, V as a trace element has been reported to have insulin mimetic/enhancing effects on type 2 diabetic rats and humans (Madsen et al., 1995; Halberstam et al., 1996; Cusi et al., 2001). Although the antidiabetic effect of V was first reported by Lyonnet and Martin (1899) more than a century ago, its potential importance as an orally active insulin-mimetic agent was described in 1985 (Heyliger et al., 1985).

Nutritional essentiality and specific deficiency sign for V in poultry and ruminant animals have not been established. In a long term experiments inducing V deficiency in growing, pregnant, and lactating goats over 15 generations using the semisynthetic feed ration by the University Jena team reported suppressed feed intake and milk production as well as reduced survival rate and reproduction efficiency accompanied by high abortion rate (Haenlein and Anke, 2011). Based on these experimentations, the authors (Haenlein and Anke, 2011) claimed that V was a nutritionally essential element at 2.0 mg per kg DM feed for goats and that no deficiency sign could occur under normal farm conditions. Drebickas (1966) reported that 0.1 mg V per kg of diet could optimize growth in calves. Farm species vary widely in their susceptibility to V toxicity, being poultry the most and being sheep the least susceptible (Suttle, 2010).

In an in vitro experiment by Tolman et al. (1979), vanadium (vanadate) is observed to enhance glucose uptake and oxidation in the in a number of in vitro assay systems in rat adipocytes. Vanadium in the form of vanadate exerts insulinomimetic effects, as reflected by the stimulation of lipogenesis and the inhibition of lipolysis in vitro (Fantus et al., 1989). Vanadyl sulfate showed to have a significant effect on the type 2 diabetic patients at 150 mg/day for a 6 weeks period (Cusi et al., 2001). In an experiment on normal subjects, 100 mg and 125 mg orally of diammonium oxy-tartratovanadate daily exhibitedd to reduce total and free cholesterol levels (Curran et al., 1959). In type 2 diabetes, it is supposed that vanadate resulted in increased insulin sensitivity in relation to enhanced non-oxidative glucose disposal (Goldfine et al., 1995). In type 2 diabetes subjects 100 mg/day of vanadyl sulfate for 3 weeks has been shown to improved insulin resistance (Cohen et al., 1995). It was hypothesized that V could augment insulin and glucose action related to energy metabolism in transition dairy cow as do in diabetic rats and humans with type 2 diabetes. Therefore, the objective of this experiment was to evaluate the effects of administration of different levels of V as vanadyl sulfate on performance and production as well as metabolic parameters in periparturient dairy cows.

2. Materials and methods

2.1. Animals, diets, and treatments

As a part of doctoral dissertation of the first authors, all experimentations with animals were performed according to the recommendations in the Guide for the Care and Use of Laboratory Animals of the Research Station of Department of Animal Science, University of Tehran, Iran. The protocols were approved by the Animal Care and Use Committee of the University of Tehran Institutional Animal Care and Use Committee and included in a Research project.

Thirty-two nonlactating pregnant multiparous Holstein cows (8 entering 2nd and 24 entering 3rd lactation) were housed in individual tie-stall and stanchion barn from 4 week before anticipated calving date through 4 week after parturition. The initial BW and BCS (±SEM) of the cows were 620 ± 11 and 3.53 ± 0.12, respectively. After matching by the lactation number and expected calving date (n = 8 blocks), cows were fed the same prepartal diet for 1 week for an adjustment period, and then assigned randomly to 1 of 4 dietary treatments: a basal diet not supplemented with V (**C**) and the basal diet supplemented with 0.04 (**LV**), 0.08 (**MV**), and 0.12 mg (**HV**) of V as vanadyl sulfate per kg $BW^{0.75}$. The basal diets for the periparturient period (Table 1) were formulated to meet nutrient demands recommended by National Research Council (2001). The cows were fed once daily during the prepartum period and twice daily during the postpartum period. The TMR was offered to receive 5% orts and water was always available.

Vanadium as vanadyl sulfate ($VOSO_4 \cdot xH_2O$, Sigma-Aldrich®, St. Louis, MO) was top dressed within 200 g of fine wheat bran at the am feeding starting from 21 d relative to the expected calving date. The prepartal dietary V level was based on BW measured on d 22 prior to the expected calving date and the postpartal dietary V level was based on BW measured individually on d 1 postpartum for each cow. The C cows received 200 g of fine wheat bran as a placebo every day during the experimental period.

2.2. Sample collection and analyses

Feeds were sampled weekly for DM content using microwave oven to update the proportion of ingredients in TMR. Moreover, feed samples were analyzed for V concentration using inductively coupled argon plasma emission spectroscopy (ICP-AES; Kanico Laboratory, Tehran, Iran).

Amounts of TMR offered and refusals were recorded daily to determine actual DMI for each cow. Body weights and BCS of individual cows were recorded weekly starting from d 22 prior to the expected calving date. Body condition scores were

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