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Genetic parameters of calcium, phosphorus, magnesium, and potassium serum concentrations during the first 8 days after calving in Holstein cows

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ABSTRACT

Calcium, Mg, P, and K are of great importance for the health and productivity of dairy cows after calving. So far genetic studies have focused on clinical hypocalcemia, leaving the genetic parameters of these macroelements unstudied. Our objective was to estimate the genetic parameters of Ca, Mg, P, and K serum concentrations and their changes during the first 8 d after calving. The study was conducted in 9 herds located in northern Greece, with 1,021 Holstein cows enrolled from November 2010 until November 2012. No herd used any kind of preventive measures for hypocalcemia. Pedigree information for all cows was available. A total of 35 cows were diagnosed and treated for periparturient paresis and, therefore, excluded from the study. The remaining 986 cows were included in genetic analysis. The distribution of cows across parities was 459 (parity 1), 234 (parity 2), 158 (parity 3), and 135 (parity ≥4). A sample of blood was taken from each cow on d 1, 2, 4, and 8 after calving and serum concentrations of Ca, P, Mg, and K were measured in each sample. A final data set of 15,390 biochemical records was created consisting of 3,903 Ca, 3,902 P, 3,903 Mg, and 3,682 K measurements. Moreover, changes of these concentrations between d 1 and 4 as well as 1 and 8 after calving were calculated and treated as different traits. Random regression models were used to analyze the data. Results showed that daily heritabilities of Ca, P, and Mg concentrations traits were moderate to high (0.20–0.43), whereas those of K were low to moderate (0.12–0.23). Regarding concentration changes, only Mg change between d 1 and 8 after calving had a significant heritability of 0.18. Genetic correlations between Ca, P, Mg, and K concentrations and their concentration changes from d 1 to 4 and 1 to 8 after calving were not significantly different from zero. Most phenotypic correlations among Ca, P, Mg, and K concentrations were positive and low (0.09–0.16), whereas the correlation between P and Mg was negative and low (−0.16). Phenotypic correlations among macromineral concentrations on d 1 and their changes from d 1 to 4 and 1 to 8 after calving varied for each macromineral. This study revealed that genetic selection for normal Ca, P, Mg, and K concentrations in the first week of lactation is possible and could facilitate the management of their deficiencies during the early stages of lactation.
Key words: macrominerals, genetic parameters

INTRODUCTION

During the first critical days after calving, Ca, P, Mg, and K blood serum concentrations are of great importance for the health and productivity of the dairy cow. Possible deviations from normal levels of these macrominerals are interrelated (Goff and Horst, 1997; Goff, 2000; Lean et al., 2013).

Calcium plays a key role at the onset of lactation (DeGaris and Lean, 2008). Hypocalcaemia (serum Ca <8.3 mg/dL) is the most important macromineral disorder of the transition dairy cow (Oetzel, 2011; Goff, 2014; Martinez et al., 2014). It is associated with health disorders including retained fetal membranes, mastitis, uterine infection, displaced abomasum, and ketosis (Correa et al., 1990; Gröhn and Bruss, 1990; DeGaris and Lean, 2008), as well as reduced dry matter intake and milk production (Rajala-Schultz et al., 1999).

Phosphorus and Mg play important roles in the etiology of hypocalcemia, as well. Hypophosphatemia (serum P <4.0 mg/dL) is involved in the manifestation of the alert downer cow syndrome, whereas elevated phosphorus concentrations increase the risk of milk fever (Lean et al., 2013; Grünberg, 2014). Hypomagnesaemia (serum Mg <1.8 mg/dL) reduces parathormone (**PTH**) secretion, tissue sensitivity to PTH, and syn-

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thesis of 1,25-dihydroxycholecalciferol (Littledike et al., 1983; Rude, 1998). Moreover, mild hypomagnesaemia (serum Mg between 1.3 and 1.8 mg/dL) is common in anorectic fresh cows and in most cases is accompanied by mild hypophosphatemia (serum P between 2 and 4 mg/dL) and mild hypokalemia (serum K between 2.6 and 3.9 mmol/L; Peek and Divers, 2008).

Potassium homeostasis in transition dairy cows is affected by numerous factors. Off-feed fresh cows, increased milk production, and concurrent diseases predispose to hypokalemia (serum K <3.9 mmol/L; Pradhan and Hemken, 1968; Sattler et al., 1998; Sattler and Fecteau, 2014).

Blood Ca concentration is considered to reach its minimum 12 to 24 h after calving and then increase gradually (Goff, 2014). Relative estimates for the other 3 macrominerals are lacking from the literature.

Serum Ca, P, Mg, and K concentrations are influenced by environmental factors, mainly nutrition (NRC, 2001; Kronqvist, 2011). Nutritional and management strategies for the prevention of these macromineral deficiencies have been developed (Bethard et al., 1998; Tauriainen et al., 2003; Rérat et al., 2009); however, a genetic component to these traits also exists, as reported for serum Ca concentration by Tveit et al. (1991).

Genetic studies so far have focused on heritability estimates of clinical hypocalcemia (milk fever) (Dyrendahl et al., 1972; Lin et al., 1989; Abdel-Azim et al., 2005) and genetic and phenotypic correlations between milk fever and various disease (Lin et al., 1989) and production traits (Lyons et al., 1991; Uribe et al., 1995; Heringstad et al., 2005). Tveit et al. (1991) reported heritability estimates for postpartum serum Ca concentrations in first-lactation Norwegian cows. However, genetic studies of serum Ca, P, Mg, and K concentrations in fresh Holstein dairy cows are lacking. Therefore, the objective of our study was to estimate the genetic parameters of Ca, Mg, P, and K serum concentrations and their changes in Holstein cows during the first 8 d after calving.

MATERIALS AND METHODS

The research was conducted in compliance with institutional guidelines and approved by the Research Committee of the Aristotle University of Thessaloniki, Thessaloniki, Greece. All farmers gave informed consent for the cows to be included in the study and the testing procedures.

Animals and Management

A total of 1,021 Holstein cows from 9 commercial freestall dairy herds in northern Greece were included in the study. The distribution across parities was 466, 242, 165, and 148 cows for parities 1, 2, 3, and ≥4, respectively. Farms were visited regularly between November 2010 and November 2012 for data collection. No herd used any kind of preventive measures for hypocalcemia. Total mixed rations were formulated to meet or exceed net energy and MP requirements according to NRC (2001) recommendations.

Clinical Examination, Blood Sampling, and Analyses

Each animal was clinically examined and blood sampled on d 1, 2, 4, and 8 after calving, by the first author. Blood samples, in all herds, were collected between 0800 and 1000 h, after the morning milking. Moreover, to standardize sampling and handling procedures, all samplings were performed in absence of unusual stressors and in proper containment systems that minimize stress and pain of the animal.

Blood sampling was performed by coccygeal venipuncture into 10-mL vacuum glass tubes without anticoagulant (BD Vacutainer, Plymouth, UK) for serum macromineral measurements. Samples were placed in a cooler, transported to the Diagnostic Laboratory of the Faculty of Veterinary Medicine, and centrifuged immediately upon arrival [3,000 × g for 15 min at room temperature (21°C)]. Serum was transferred into polyethylene tubes and stored at −80°C until assay. All sera were analyzed for total Ca and Mg concentrations using flame atomic absorption spectrophotometry (Perkin ElmerAAnalyst 100, Perkin Elmer Co, Norwalk, CT) according to the manufacturer's instructions. Serum inorganic phosphorus concentrations were determined photometrically using a Flexor E autoanalyzer (Vital Scientific, Spankeren, the Netherlands), according to the procedure described by Daly and Ertingshausen (1972), with the use of standard commercial reagents (Thermo Fisher Scientific, Waltham, MA). Potassium serum concentrations were measured using an ion-selective electrode according to manufacturer's instructions (Electrolyte Analyzer 9180, Roche, Basel, Switzerland). The intra- and interassay coefficients of variation for all the above analyses were less than 3%.

Dataset

Considering that pedigree information was available for all cows, the total population increased to 4,262 animals, spanning the last 5 generations. Calving date, parity number, calving ease, and twinning was recorded.

A total of 35 cows were diagnosed with periparturient paresis, treated appropriately with intravenous Ca, and excluded from the study. Therefore, the remaining 986 cows were finally included in the genetic analysis. The