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THE ROLE OF BORON IN ANIMAL HEALTH

Mustafa Kabu[1], Cangir Uyarlar[2], Katarzyna Żarczyńska[3], Wanda Milewska[4], Przemysław Sobiech[3]

[1]Department of Internal Medicine
[2]Department of Animal Nutrition and Nutritional Diseases
Afyon Kocatepe University
[3]Chair of Internal Disease
[4]Chair of Pig Breeding
University of Warmia and Mazury in Olsztyn

Abstract

Boron is a mineral used for various purposes in glass, ceramics, automotive and paint industries. Recently, boron has been confirmed to be an essential element for plants, animals and humans, although the knowledge of its biological effects is rather scanty. Boron is a dynamic trace element, and inorganic borates are transformed into boric acids and absorbed from mucosal surfaces, even when they are in low levels of physiological pH. It has been determined that boron affects many enzymes, bone development, mineralization, Ca, P, Mg and energy metabolism. Boron mineral compounds can be effective in optimizing the performance of an organism, treatment of bone structure disorders, reduction of cholesterol and triglyceride levels. Beside the effects it produces specifically on fat and lipid metabolisms, boron can influence the activity of vitamin D and affect some disorders connected with its deficiency. Although several studies on effects of boron on some mechanisms have been conducted over the last ten years, the available information remains insufficient.

Key words: boron, enzymes, hormones, minerals, animal health.

dr hab. Przemysław Sobiech, prof UWM, Chair of Internal Disease, Faculty of Veterinary Medicine, University of Warmia and Mazury, Oczapowskiego 14, 10-719 Olsztyn, Poland, e-mail: psobiech@uwm.edu.pl

INTRODUCTION

Boron, assigned the symbol B in the periodic table of elements, is a semi-conductor classified between metals and nonmetals. It is generally found in compounds with other elements. There are approximately 230 types of boron minerals. By binding with oxygen, various boron-oxygen compounds called borates are created (Loomis, Durst 1992).

Boron is reported to be essential for plants and, in recent studies on its biological significance in various metabolic, nutritional, hormonal and physiological circumstances, has been determined to be essential for humans and animals as well. There are ongoing studies on its effects on metabolism. Boron, which is a micromineral, is acquired by humans and animals from food on a daily basis, depending on its amount in food and drink consumed (Kabu, Akosman 2013).

Boron is a dynamic trace element, and inorganic borates are transformed into boric acids and absorbed from mucosal surfaces, even when they are in low levels of physiological pH. More than 90% of borate used in research on humans and animals is excreted as boric acid. In *in vitro* and *in vivo* systems, boric acid shows an affinity to cis-hydroxyl groups, which is reported to be the reason for some mechanisms underlying the biological effect of boric acid (WHO 1998, Bolaños et al. 2004).

IMPORTANCE OF BORON FOR THE PROGRESSION OF LIFE

The plasma concentration of boron is under homeostatic control and boron seems to play a regulatory role in mineral metabolism although the mechanism of its action remains unclear. Boron supplementation causes high plasma concentrations of iron and copper, independently of the dietary vitamin D_3 concentration. Boron added at a concentration of 5 mg kg^{-1} to diets with an adequate and inadequate vitamin D_3 supply decreased the plasma zinc concentration (Kurtoglu et al. 2005). Nielsen et al. (1992) reported that boron supplementation reduced the zinc concentration in bone, but did not influence the concentration of this element in serum.

Researchers have argued that sodium borate ($Na_2B_40_7$) plays a protective role against fatty liver disease (Basoglu et al. 2002). In a study conducted by Basoglu et al. (2002), significant decreases in serum triglyceride (TG) and the content of very low-density lipoprotein (VLDL) were detected in animals that were administered with sodium borate. It was reported that the use of sodium borate (100 mg kg^{-1} b.w.) during early lactation of dairy cattle might reduce the incidence of fatty liver. Because treatment of fatty liver is costly and difficult, prevention of this syndrome is more important than therapy. Boron mollifies the negative effects observed in liver failure (by changing the oxidative stress parameters) and partially normalizes the liver (Pawa, Ali 2006). In another study carried out on dogs (Basoglu et al. 2000), it was

proven that sodium borate ($Na_2B_40_710H_2O$) was effective in keeping plasma lipid levels low. Moreover, one week after the start of sodium borate application, a decrease in glucose, insulin and apolipoprotein B-100 levels was detected; and after the second week, a decrease in VLDL and TG levels was also seen (Basoglu et al. 2000).

In molecular studies, boron was reported to be effective in at least 26 different enzymatic activities, most of which are necessary for energy substrate metabolism (Hunt 1998). There are studies declaring that boron alone increased plasma glucose concentrations, especially when there was vitamin D deficiency (Hunt et al. 1994). Boron deficiency in rats promoted the deficiency of vitamin D, which was reported to have likewise significantly decreased plasma TG concentrations, and increased plasma pyruvate concentrations (Hunt, Herbel 1991-1992). Many researchers have reported that boron added in physiological amounts to a diet for chickens lessens the increase of plasma glucose observed in cases of vitamin D deficiency (Bakken, Hunt 2003, Hunt et al. 1994). It is not exactly clear how boron deficiency, especially in suboptimal food amounts, affects the energy substrate metabolism of animal models (Bakken, Hunt 2003). Boron deficiency has been reported to cause hyperinsulinemia in rats which were deprived of vitamin D (Hunt, Herbel 1991-1992). Boron deficiency may increase the amount of fasting serum glucose in people on a low magnesium diet (Nielsen 1989). There are some studies concerning the role of boron in insulin secretion (Bakken, Hunt 2003). A low plasma insulin concentration resulting from an addition of boron, which does not change plasma glucose, can be interpreted as a consequence of the reduced amount of insulin necessary for maintaining plasma glucose concentrations. It is also claimed that boron acts as a direct stimulus for insulin secretion (Bakken, Hunt 2003).

The results presented by Kurtoglu et. al. (2001) indicated that boron had influence on the plasma calcium content and alkaline phosphatase (AP) activity, especially at low dietary concentrations of D_3 (6.25 μg kg^{-1}). There is considerable evidence that dietary boron alleviates perturbations in mineral metabolism that are characteristic of vitamin D_3 deficiency (Kurtoglu et al. 2001). There are three particular mechanisms involved in the boron-vitamin D_3 interaction: boron compensates for perturbations in energy-substrate utilization; boron enhances the macromineral content of normal bone; dietary boron (independently of vitamin D) can enhance some indices of growth cartilage maturation (Kurtoglu et al. 2005). In the study performed by Elliot and Edwards (1990), in which they used a factorial arrangement of treatments involving an addition of calcium, cholesterol and boron (3 mg kg^{-1}) to purified diets for broilers, boron supplementation tended to increase bone ash, and there was a significant interaction between the effects of boron and cholecalciferol on weight gain. Another study (Bakken, Hunt 2003) revealed interactions between boron, magnesium and vitamin D metabolism. Magnesium 25-hydroxycholecalciferol is the cofactor in hydroxylation of D_3. Boron added to diets of chickens that had an induced magnesium deficiency (300 mg kg^{-1})

was reported to have fostered growth (Bakken, Hunt 2003). The studies carried out up to date have revaled that the relationship between boron and magnesium is more effective than that between calcium and phosphorus. However, it has been suspected that boron does not affect magnesium metabolism directly but through an indirect interaction with magnesium metabolism, possibly by affecting some enzymatic or hormonal systems, due to low molecular levels of boron/magnesium in plasma and in a diet (Bakken, Hunt 2003).

There are a few reports on the effects of boron on inflammatory processes in an organism. Armstrong et al. (2001) showed that boron supplementation (5 mg kg^{-1}) significantly depressed the inflammatory response against intradermal injections of phytohaemagglutinin in pigs. In another study (Armstrong, Spears 2003), it was found that pigs fed for a long time a diet containing boron in the concentration of 5 mg kg^{-1} developed an elevated TNF-α and IFN-γ production by monocytes. Nevertheless, boron did not affect the mitogenic response of lymphocytes to mitogenic stimulation or the humoral immune response against sheep red blood suspension (Fry et al. 2010).

What makes the interpretation of the above research results difficult is the differences between doses of boron in diets, use of different boron resources, absence of a calculated absorption rate and the discrepancy between a boron dose in real diets of people and animals and doses determined in basal diets. It has been stated that diets based on corn, rice, wheat and rye are low in boron (<0.2 mg kg^{-1}) while fruits, vegetables and nuts contain more boron (Loomis, Durst 1992).

EFFECT OF BORON ON SOME ENZYMES, HORMONES AND MINERALS

Some enzymes from both classes related to the energy substrate mechanism can be inhibited by boron. In the glycolytic path, glyceraldehyde-3-phosphate dehydrogenase (G3-PD) is responsible for transforming D-glyceraldehyde-3-phosphate into 1.3-diphosphoglycerate. Adenosine triphosphate (ATP) and nicotinamide adenine dinucleotide (NAD) regulate the activity of G3PD (Hunt 1994). ATP disassociates the enzyme while NAD is responsible for its reassociation (Hunt 1994). Boron has been reported to bond to specific parts of the enzyme, changing its structure and causing disassociation of tetramers (Hunt 1994). *In-vitro* studies have reported that certain enzymes in energy substrate metabolism paths have been inhibited or regulated by boron (Hunt 1994). There are some studies saying that in a case of vitamin D3 deficiency, dietary boron supplementation is effective in changing glucose levels, but the results are insufficient to draw a firm conclusion (Hunt 1994).

Kabu et al. (2014) tried to evaluate potential effects of boron (30 g per day), propylene glycol and methionine on some haematological parameters in dairy cattle during the periparturient period. There were no differences in the number of white blood cells, lymphocytes, monocytes, neutrophil gran-

ulocytes, red blood cells, platelets and mean platelet volume after this supplementation. A statistically significant difference was established between the groups in the levels of mean cell volume and haematocrit on calving, haemoglobin at 2 weeks postpartum, mean cell haemoglobin concentration at 1 week prepartum and 2 weeks postpartum. This study suggests that administration of boron, propylene glycol and methionine had transient effects on some of haematological parameters of ruminants in the periparturient period.

Kabu et al. (2013) studied the effects of boron (dose 30 g per day) on concentrations of serum calcium (Ca), magnesium (Mg) and phosphorus (P) in dairy cattle in the peripartum period. Serum Ca and Mg increased in a group with addition of boron, while the P concentration was unaffected by this element. The results suggest that sodium borate may be useful for sustaining metabolic balance and perhaps preventing metabolic disorders such as milk fever and hypomagnesaemia in dairy cattle during the periparturient period (Kabu et al. 2013).

In a study performed by Hall et al. (1989), low-density lipoprotein (LDL) cholesterol and TG levels in rats decreased after 14 days of addition of boron agent. This decrease inhibited LDL bonding and LDL entrance into liver cells, fibroblasts, and aorta cells while increasing high-density lipoprotein (HDL) bonding and its accumulation in liver cells. This development was claimed to be beneficial for atherosclerosis patients because it may cause the disposal of cholesterol from tissues and a decrease in the accumulation of lipids (Devirian, Volpe 2003). In the study carried out by Naghii and Samman, (1997*a*,*b*), boric acid was reported to decrease total cholesterol, HDL_3, TG, and total HDL when it was given to rats for two weeks at a dose of 2 mg/day.

Another study was carried out on 36 Angus and Angus-Simmental cattle (Fry et al. 2010) to determine the effects of boron on resistance to bovine herpesvirus type-1 (BHV-1). The animal were fed diets with addition of boron. BHV-1 was inoculated in the cattle intranasally. Plasma B concentrations had slightly increased after the addition of B, while dietary B showed no effect on the process and on the significance of BHV-1 symptoms as well as having little influence on plasma acute phase proteins and cytokines (Fry et al. 2010).

Kabu and Civelek (2012) studied the effects of sodium borate ($Na_2B_4O_7$ $5H_2$, 30 g/day) orally administrated to 12 pregnant cows on selected hormone levels and serum metabolites. There were no differences in concentration of total protein (TP), albumin (ALB), blood urea nitrogen (BUN), alanine aminotransferase (ALT), total bilirubin (TBil), aspartate aminotransferase (AST), and gamma-glutamyltransferase (GGT). Glucose levels were higher during the prepartum period, and the postpartum glucagon and β-hydroxybutyric acid (BHBA) serum levels were higher in the unsupplemented group. (Kabu, Civelek 2012). After sodium borate administration, concentrations of total cholesterol (TChol), triglyceride (TG), high-density lipoprotein (HDL),

low-density lipoprotein (LDL), very low density lipoprotein (VLDL), glucose, insulin, and nonesterified fatty acids (NEFA) in blood were decreased (Kabu, Civelek 2012).

CONCLUSIONS

To conclude, boron is thought to be an essential element for animals, people and plants. Although many countries have boron deposits, the number of studies on the effects of the element boron on fertility and general health performance is limited. Effects of boron on human and animal bone development, mineralization, Ca, P, and Mg metabolism, energy metabolism, and enabling enzyme activation have been proven by scientific studies. While evaluating the results of these studies, it has been suggested that boron minerals can be effective in optimizing performance of an organism, treatment of bone structure disorders, reduction of cholesterol related to lipid metabolism, and reduction of triglyceride levels. Further research and implementation of the results are needed in order to determine a dose of boron and boron compounds that can be positive in animal rations, to ascertain its effects on other metabolisms and certainly to explain its biochemical functions.

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