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Influence of Biochrome® on the Response of Metabolic Hormones in PEMS-Infected Poults[1]

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ABSTRACT Poult enteritis and mortality syndrome (PEMS), a disease that affects turkeys between 7 and 28 d of age, causes a severe inflammation of the intestinal tract and is characterized in poults by severe diarrhea, high morbidity, mortality, and stunting. The PEMS-associated mortality and growth depression is related to malabsorption and decreased metabolic activity caused, in part, by a possible insulin deficiency or insensitivity. Insulin receptors are stimulated by the glucose tolerance factor (GTF) that incorporates Cr. Body Cr deficiency can be exacerbated by dietary deficiency and by increased excretion due to stress associated with a diarrheal disease such as PEMS. BioChrome® (BC) contains natural, preformed GTF, the bioactive form of Cr. Experiments were conducted in which BC was blended into poult starter feed at 400 ppb during the first 21 d posthatch. Body weights were determined at 1, 7, 14, and 21 d of age, and weekly feed conversions were calculated for each treatment group (control, BC, PEMS, and BC+PEMS). At 6 d posthatch, each PEMS-designated poult was given a 0.1-mL oral gavage of a 10% suspension of feces from PEMS-infected poults. Blood samples were taken via cardiac puncture from four birds per treatment group at 7, 10, 14, 17, and 21 d of age. Radioimmunoassays were conducted for plasma insulin, glucagon, thyroxine (T_4), and triiodothyronine (T_3). Plasma insulin levels were depressed in PEMS-infected poults from Days 10 through 17, but plasma glucagon levels in the PEMS-infected poults were significantly elevated at 14 and 17 d, after which they returned to control levels in both of the PEMS-infected groups. The T_3 and T_4 levels were depressed through Day 21 in PEMS-infected poults, but with BC treatment these blood hormone levels rebounded by Day 21. Body weights of PEMS-infected poults were increased significantly by the BC treatment but not to the level of noninfected controls.

(*Key words*: poult, enteritis, mortality, hormone, chromium)

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INTRODUCTION

Poult enteritis and mortality syndrome (PEMS) is an acute, transmissible, infectious, enteric disease that affects young turkeys between 7 and 28 d of age (Barnes et al., 1996, 1997). The PEMS problem is complicated by the fact that no etiological agents have been identified (Barnes and Guy, 1995; Brown, 1995; Barnes et al., 1996; Barnes, 1997; Edens et al., 1997a,b,c; Qureshi et al., 1997).

During the development of this diarrheal disease, many poults experience severe wasting of body musculature. The wasting of the musculature and loss of nearly all of the adipose tissues suggests that even though the poults are eating some feed, nutrient intake is not sufficient to meet body requirements for maintenance and growth (Edens et al., 1997a,b,c; Qureshi et al., 1997). Therefore, malabsorption and metabolic dysfunction could be contributing to the disease. Indeed, absorption of D-xylose was inhibited significantly in PEMS-infected poults (Doerfler et al., 2000), clearly indicating that part of the wasting syndrome in PEMS is due to their inability to absorb sufficient quantities of nutrients from the gastrointestinal tract.

In field cases of PEMS, hypoglycemia and hypophosphatemia have been suspected as contributors to the disease (Edens and Doerfler, 1997a,b; Doerfler et al., 1998). Providing PEMS-infected poults with sugar and phosphate in drinking water showed that the diseased poults were not able to absorb adequate amounts of either glucose or phosphate from the intestinal tract. Even more vital, it appeared that PEMS-infected poults had an impaired capability for utilization of glucose from the circu-

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[1]The use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Research Service, Raleigh, NC, of the products named nor criticism of similar products not mentioned.

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Abbreviation Key: BC = BioChrome®; PEMS = poult enteritis and mortality syndrome; GTF = glucose tolerance factor; T_3 = triiodothyronine; T_4 = thyroxine; IGF = insulin-like growth factor(s); FCR = feed conversion ratio.

latory system, which may potentially be attributed to decreased levels of many metabolically active hormones such as insulin and insulin-like growth factors (Edens and Doerfler, 1997a,b; Doerfler et al., 1998). This assessment was based upon the inability of PEMS-infected poults to synthesize hepatic glycogen or to downregulate hepatic glucose-6-phosphatase, an enzyme that is pivotal in the metabolism of glucose for energy and for glycogen synthesis (Edens et al., 1997a; Edens and Doerfler, 1997a,b; Doerfler et al., 1998). These observations confirmed a severe malabsorption condition (Doerfler et al., 2000) and a serious metabolic dysfunction in PEMS-afflicted poults (Edens et al., 1997a; Edens and Doerfler, 1997a,b; Doerfler et al., 1998).

Reduced levels of hepatic glycogen in the affected poults could be due in part to an insulin deficiency. Insulin is a hormone that promotes anabolic processes and inhibits catabolic processes in muscle, liver, and adipose tissues. The action of insulin is stimulated by the glucose tolerance factor (GTF), with Cr as its active component. Hence, Cr stimulates and regulates the action of insulin, although the underlying mechanism is not clear (Roginski and Mertz, 1969; Kahn, 1978). However, Evans and Bowman (1992) have shown that Cr facilitates insulin internalization in cells in vitro, as well as an increase in the uptake of glucose and leucine. Chromium is an essential trace element required for the normal metabolism of both lipids and carbohydrates. The status of Cr in animals can be diminished by poor availability in the feed, feed quality with high levels of simple sugars, infection, physical trauma, and elevated excretion due to stress associated with a diarrheal disease (Anderson, 1986, 1994).

Chromium deficiency can disrupt carbohydrate and protein metabolism, reduce insulin sensitivity in peripheral tissues, impair growth rate, and cause animals to be very susceptible to many different types of stressors (Doisy, 1978; Anderson, 1986, 1994; Mowat, 1994; Mowat et al., 1995; Pagan et al., 1995; Lindeman, 1996). Anderson (1986) reported that supplementation of Cr to normal individuals often leads to improved glucose tolerance, serum lipids, insulin, and insulin binding. Anderson (1986, 1994) further noted that Cr normalizes blood sugar levels. In individuals with hyperglycemia following a glucose load, Cr supplementation causes a decrease in blood glucose levels. Conversely, hypoglycemics respond to Cr by increased blood glucose levels, increased insulin binding, and alleviation of hypoglycemia signs.

Organic Cr sources provide more bioavailability (25 to 30%) than inorganic Cr sources, of which only about 0.5 to 3.0% is absorbed (Mowat, 1994). Furthermore, the trivalent Cr found in BioChrome®,[3] (BC) has very low toxicity and is often supplemented in diets for athletes or in diets for people subjected to stress (Mordenti et al., 1997). In an attempt to ameliorate the devastating effects caused by PEMS, BC, a chromium yeast, was incorporated into the diet of control and PEMS-exposed turkey poults. We hypothesized that addition of BC to the diets of PEMS-infected turkeys, known to suffer from hypoglycemia and other disturbances in glucose metabolism (Edens et al., 1997a; Edens and Doerfler, 1997a,b; Doerfler et al., 1998), might provide the additional nutrients and energy necessary to sustain them through the most severe phase of the disease.

MATERIALS AND METHODS

Animal Welfare

This project was approved and conducted under the supervision of the North Carolina State University Animal Care and Use Committee, which has adopted Animal Care and Use Guidelines governing all animal use in experimental procedures.

Poults and Husbandry

Hybrid female turkey poults were obtained and transported from a commercial hatchery to North Carolina State University. These day-old poults were wing-banded, weighed, and placed into pens in heated metal battery brooders with raised wire floors, where water and turkey starter feed (North Carolina Agricultural Research Service: 2,915 kcal/kg metabolizable energy and 28.13% crude protein) with or without BC (400 ppb as a dry powder blended into the feed) were provided ad libitum. With the exception of the Cr in BC, Cr was not added to the diets of these turkeys. Dietary content of Cr was not ascertained.

Fifteen poults were housed in each pen within each brooding battery, and there were eight pens of 15 poults per treatment. The poults were not subjected to hatchery services such as beak or toe trimming, antibiotic administrations, or vaccinations. Continuous lighting was provided by incandescent lamps in the ceiling of each room and on each deck of the brooding battery. At the time of placement, the control and PEMS-exposure designated poults were assigned to separate, but identical, controlled-environment isolation rooms.

Brooding Temperatures

Ambient temperature for brooding was maintained by room air conditioning with a thermostatically controlled hot-and-cold water heat exchange system mediated by forced draft. Initial room brooding temperature for the control and PEMS rooms was set at 34 C, and this temperature was decreased 3 C in each room at 7, 14, and 21 d of brooding. Humidity in the experimental rooms was not controlled and varied from 47 to 63% relative humidity.

Experimental Design

The experiment utilized a factorially arranged 2 (control vs. PEMS) × 2 (with or without BC) × 8 (replicates per

[3]Alltech, Inc., Alltech Biotechnology Center, 3031 Catnip Hill Pike, Nicholasville, KY 40356.

TABLE 1. Influence of BioChrome® (BC) on the performance of poult enteritis and mortality syndrome (PEMS)-infected 21-d-old female turkey poults[1]

	Treatment groups			
Performance characteristic	Control	BC	PEMS	PEMS+BC
Mortality, %	1.3 ± 0.08[b]	1.2 ± 0.06[b]	40.0 ± 2.44[a]	37.6 ± 2.12[a]
BW, g	490 ± 41[a]	491 ± 35[a]	213 ± 23[c]	281 ± 16[b]
FCR, g feed/g BW	1.87 ± 0.02[d]	1.98 ± 0.03[c]	3.72 ± 0.11[a]	2.50 ± 0.10[b]

[a–d]In a row, means with unlike superscripts differ significantly ($P \leq 0.05$).

[1]Results of two experiments with eight replicate pens of 15 poults per treatment in each experiment. BioChrome® is the source of natural chromium in yeast, and it was added to the feed at 400 ppm. The PEMS infection was induced at 5 d of age.

[2]Feed conversion ratio.

treatment: control, BC, PEMS, and PEMS+BC) completely randomized experimental design. A total of 960 poults was used in two experiments (480 per experiment).

PEMS Exposure

At 5 d posthatch, each poult in the PEMS-exposed groups was given a 0.1-mL oral gavage of a 10% suspension of feces from PEMS-positive, Coronavirus-negative poults maintained at the College of Veterinary Medicine at North Carolina State University.

Measurements

In Experiments 1 and 2, BW were taken at placement and at 7-d intervals through 21 d of age. Blood samples for plasma from the ulnar vein in the wing were obtained twice weekly from four birds per treatment group, and these were analyzed for a series of metabolically active hormones and other blood chemistries. Blood samples were collected from full-fed poults. The samples were collected in sodium heparin in blood collection vials. Plasma samples for glucagon assays were stored in the presence of aprotinin.[4] Radioimmunoassays for thyroxine (T_4) and triiodothyronine (T_3) were conducted by using procedures for turkeys as reported by Edens et al. (1991). Double antibody radioimmunoassays for insulin (McMurtry et al., 1983), insulin-like growth factor (IGF)-I (McMurtry et al., 1994), and IGF-II (McMurtry et al., 1998) and a commercial kit for glucagon[5] (using porcine glucagon antibody that cross-reacts with avian glucagon) were conducted in the laboratory of John P. McMurtry at USDA-ARS, Beltsville, MD. All samples were assayed in one assay to avoid interassay variation. Birds that died during the week were weighed, and their weight gain was included in calculations of weekly feed conversion ratios (FCR; g feed/g BW gain).

Analysis of Data

Preliminary analysis of the data indicated no differences attributable to experiment. Therefore, all blood plasma and BW data for the two experiments were combined and subjected to analysis of variance with the general linear models procedure of SAS® software (SAS Institute, 1996). Statements of significance were based on $P \leq 0.05$ as a minimum level of significance.

RESULTS AND DISCUSSION

The use of BC in diets of control and PEMS-infected poults did not affect mortality rates, and as expected, PEMS mortality rates were elevated significantly (Table 1). In control poults, BC did not influence BW, but in PEMS-infected poults, BC induced a small, but significant, increase in BW by the time the birds were 21 d of age (Table 1). We determined the influence of BC on feed to BW FCR in normal and PEMS-infected poults. These FCR data confirmed that BC had improved FCR in the PEMS-infected poults. The BC-treated, PEMS-infected poults ate less feed but were more efficient in converting it to body mass, possibly indicating improved carbohydrate and lipid metabolism and improved nutrient uptake from the intestine. This response would not account for a significant FCR increase in BC alone or PEMS with BC supplementation. The significantly elevated FCR in PEMS alone was related to diarrhea, decreased feed intake, and malabsorption of nutrients. However, the increase in FCR associated with BC supplementation probably was related to elevated levels of metabolically active hormones such as the thyroid hormones (Table 2; Figures 3 and 4), which were greater in control and BC-treated poults than in PEMS alone. Hepatic glycogen was being synthesized (Table 3), IGF-I and -II were elevated (Table 2 and Figures 5 and 6), and BW of BC-fed, PEMS-infected poults were elevated by nearly 132% (Table 2) in comparison with PEMS-infected poults without BC. These changes in the levels of metabolically active hormones, metabolites, and BW account for the significant interaction among treatments noted for each measurement. For these observations to be made, PEMS-infected poults with BC supplementation had have more efficient feed use to meet metabolic needs for energy production and weight accretion.

In control and PEMS treatments, BC supplementation in the feed did not affect overall plasma insulin levels (Table 2), but a time effect showed that plasma insulin in PEMS-infected poults was depressed significantly from

[4]Sigma Chemical Co., St. Louis, MO 63178.

[5]Linco Research, Inc., St. Charles, MO 63304.

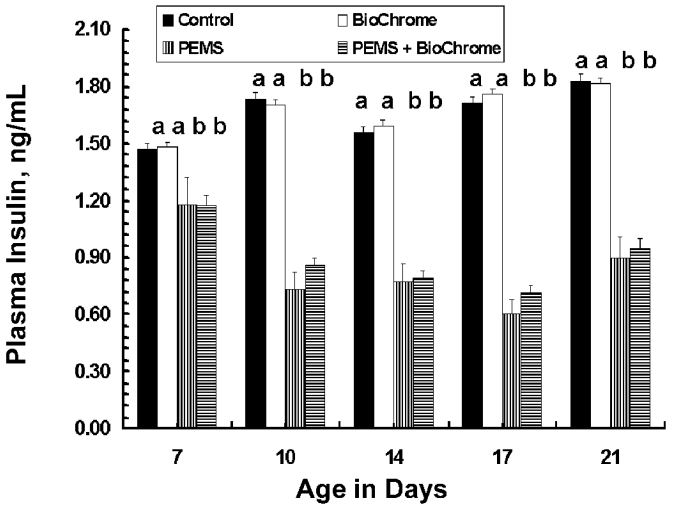

FIGURE 1. Time course of plasma insulin responses for control, BioChrome,® PEMS, and BioChrome®+PEMS treatment groups. Poults in the PEMS-exposed groups were given a single oral inoculation when they were 6 d of age. [a,b]Within days of age, significant differences ($P \leq 0.05$) among treatment groups are indicated by different lowercase letter headings.

Days 10 to 21 in comparison to noninfected poults (Figure 1). A significant elevation in plasma glucagon in BC-treated control poults from 7 to 21 d of age was mirrored by elevated glucagon levels in BC-treated, PEMS-infected poults from 10 to 21 d of age (Table 2; Figure 2). By Day 21, plasma glucagon in PEMS-infected poults without BC treatment was also increasing but not to the same extent as the PEMS-infected poults with BC treatment (Figure 2). These observations explain a significant time × treatment interaction for plasma glucagon.

The use of BC in the feed of control poults was associated with elevated levels of plasma T_4 and T_3 (Table 2; Figures 3 and 4, respectively). The PEMS infection from Days 10 through 21 of age caused decreased plasma T_4 and T_3 (Table 2; Figures 3 and 4, respectively) levels that did not rebound after birds appeared to have overcome the infection. BioChrome® supplementation to the feed ameliorated the PEMS-associated decreases in plasma T_4 and T_3 (Figures 3 and 4, respectively) to the level of noninfected controls for T_3 at 21 d but not for T_4. In previous studies, PEMS infection was associated with significantly decreased plasma levels of insulin, T_4, and T_3 and elevated levels of plasma glucagon (Edens and Doerfler, 1997a; Doerfler et al., 1998). There were significant time × treatment interactions for T_4 and T_3.

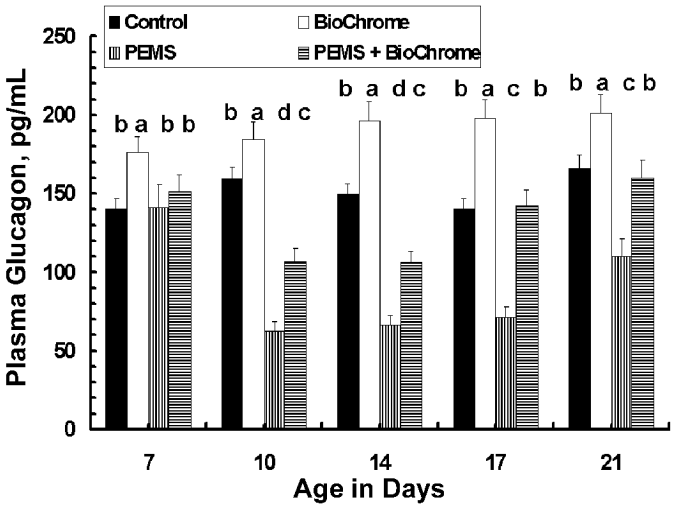

FIGURE 2. Time course of plasma glucagon responses for control, BioChrome,® PEMS, and BioChrome®+PEMS treatment groups. Poults in the PEMS-exposed groups were given a single oral inoculation when they were 6 d of age. [a–d]Within days of age, significant differences ($P \leq 0.05$) among treatment groups are indicated by different lowercase letter headings.

Feed supplemented with BC resulted in elevated plasma IGF-I in control poults (Figure 5). BioChrome® influenced plasma IGF-II in only one instance, at 10 d of age (Figure 6). In the PEMS-infected poults (Figures 5 and 6, respectively), BC supplementation elicited significant elevation in plasma IGF-I and IGF-II to a level similar to and even exceeding noninfected controls at 21 d of age. The PEMS infection without supplemental BC significantly depressed IGF-I and IGF-II (Figures 5 and 6, respectively). Significant time × treatment interactions were found for IGF-I and IGF-II.

Plasma glucose was elevated in PEMS-exposed poults that had survived the high mortality period of the disease (Table 2; Figure 7). Plasma glucose was not affected by feed supplemented with BC (Table 2, Figure 7). However, an interesting BC effect was found in the hepatic glycogen response to PEMS (Table 3). In earlier studies we reported a significant depression in hepatic glycogen in PEMS-infected poults (Doerfler et al., 1998), and in the current study a similar response was observed. However, in the BC-supplemented, PEMS-infected poults, hepatic glycogen levels were comparable to levels found in noninfected controls. In view of the observation that plasma glucose can be decreased with injections of IGF-I and IGF-II (McMurtry et al., 1996, 1997), one must assume that the glucose uptake in the liver of PEMS-infected poults treated with BC had to be facilitated by the BC-elevated IGF. Hepatic glucose-6-phosphatase activity in PEMS survivor poults was near the levels found in noninfected control poults (Table 3). The decrease in hepatic glucose-6-phosphatase activity would be expected if glucose uptake was mediated by elevated blood glucose or by stimulation of insulin receptors by insulin or IGF (McMurtry et al., 1996, 1997). Therefore, BC-related increases in IGF may have stimulated hepatic uptake of glucose in PEMS-infected poults, resulting in a significant decrease in glucose-6-phosphatase activity.

Although BC did not reduce mortality associated with PEMS, a small but significant increase occurred in BW of the infected poults given the feed supplement (Table 1). This increase in BW appeared to be related to altered levels of metabolically active plasma hormones. The hormones of primary interest in this study were the thyroid hormones and insulin. In a previous study (Doerfler et al., 1998), severe hypothermia, hypothyrosis, and hypoglycemia were documented for the first time in PEMS-

TABLE 2. Influence of BioChrome® on overall mean[1] plasma constituents in poult enteritis and mortality syndrome (PEMS)-infected female turkey poults

	Treatment groups			
Plasma chemistry	Control	BC	PEMS	PEMS+BC
Insulin, ng/mL	1.6 ± 0.15[a]	1.6 ± 0.11[a]	0.8 ± 0.21[b]	0.9 ± 18[b]
Glucagon, pg/mL	151 ± 12[b]	192 ± 9[a]	91 ± 15[c]	132 ± 14[b]
Thyroxine, ng/mL	7.6 ± 0.5[b]	10.3 ± 1.0[a]	1.9 ± 0.5[c]	5.7 ± 0.7[b]
Triiodothyronine, ng/mL	1.8 ± 0.2[b]	2.5 ± 0.3[a]	0.8 ± 0.4[c]	2.3 ± 0.3[a]
IGF[2]-I, ng/mL	3.2 ± 0.5[c]	5.4 ± 0.4[a]	0.7 ± 0.3[d]	4.9 ± 0.3[b]
IGF-II, ng/mL	13.0 ± 1.7[a]	13.7 ± 1.9[a]	7.3 ± 2.1[b]	15.2 ± 2.5[a]
Glucose, mg/dL	200 ± 15[b]	210 ± 12[b]	242 ± 17[a]	221 ± 11[ab]

[a–d]In a row, means with unlike superscripts differ significantly ($P \leq 0.05$).

[1]n = 20 per observation.

[2]Insulin-like growth factor.

infected poults. Additionally, Edens and Doerfler (1997a,b) and Doerfler et al. (1998) reported that PEMS-infected poults appear unable to absorb glucose from the intestine and to utilize blood glucose in the liver. These problems were attributed to the decreased level of metabolically active hormones in the circulatory system. This condition in PEMS creates a paradox because PEMS-related hypoglycemia inhibits insulin secretion. Normally, in the liver and under the influence of insulin, glucose is converted to fatty acids, but in PEMS this does not appear to occur (Edens and Doerfler, 1997a). In PEMS-infected poults, liver weights are decreased and hepatic mitochondria are severely damaged (Edens and Doerfler, 1997b). Insulin inhibits proteolysis and enhances protein and amino acid sequestration in all target tissues (Berne and Levy, 1993). In PEMS-infected poults, muscle wasting and lipolysis are evident (Edens and Doerfler, 1997a,b), suggesting that insulin is not functioning properly or that it is decreased significantly as reported herein.

The plasma insulin profile in PEMS-infected poults noted in this study strongly suggests that wasting and reduced growth of the infected poults are attributed to low levels of insulin. However, the supplementation of BC in the diet of these PEMS-infected poults did not elevate plasma insulin, but BW did have a small but significant increase in the BC-supplemented birds. In addition, hepatic glycogen levels were elevated and hepatic glucose-6-phosphatase activity decreased in the PEMS-infected, BC-supplemented poults, indicating that they had likely responded to BC by becoming more sensitive to the lower levels of available plasma insulin.

Insulin, along with growth hormone, regulates the transcription of related growth factors, such as IGF-I and IGF-II (Houston and O'Neill, 1991). Additionally, receptors for insulin will recognize IGF (IGF-I and IGF-II) and insulin because of close structural similarities (Rechler, 1985; Prosser, 1991; McMurtry et al., 1996, 1997). Fasting, protein deprivation, and insulin deficiency all lead to diminished synthesis and secretion of the IGF (McMurtry et al., 1996, 1997; McMurtry, 1998). A significant depression in plasma levels of IGF-I and IGF-II were found in PEMS-infected poults in this study. However, with the supplementation

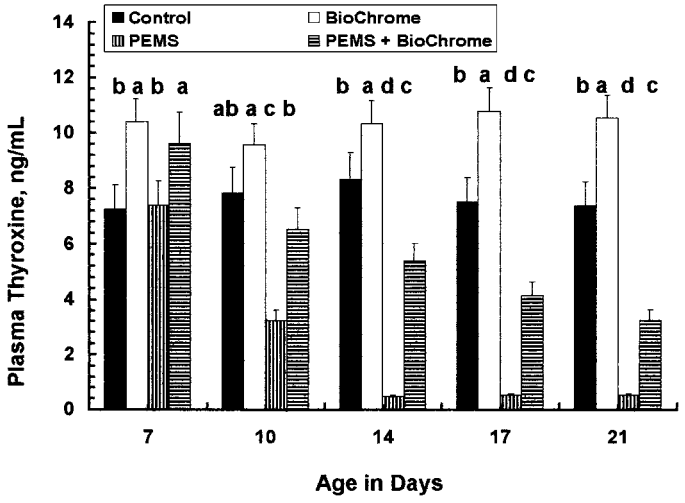

FIGURE 3. Time course of plasma thyroxine responses for Control, BioChrome,® PEMS, and BioChrome®+PEMS treatment groups. Poults in the PEMS-exposed groups were given a single oral inoculation when they were 6 d of age. [a–d]Within days of age, significant differences ($P \leq 0.05$) among treatment groups are indicated by different lowercase letter headings.

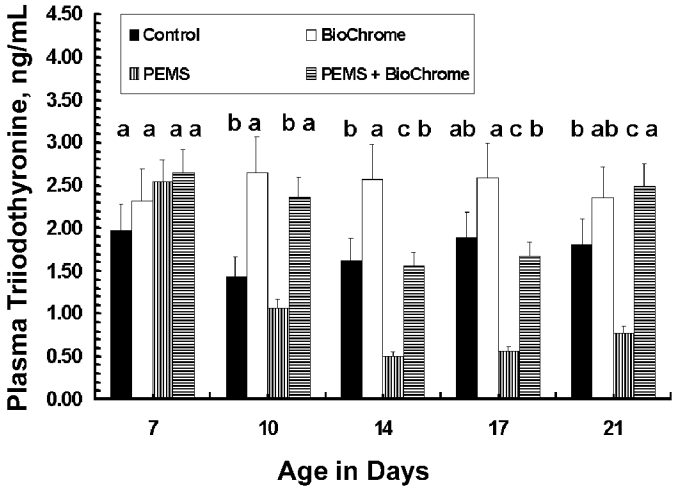

FIGURE 4. Time course of plasma triiodothyronine responses for Control, BioChrome,® PEMS, and BioChrome®+PEMS treatment groups. Poults in the PEMS-exposed groups were given a single oral inoculation when they were 6 d of age. [a–c]Within days of age, significant differences ($P \leq 0.05$) among treatment groups are indicated by different lowercase letter headings.

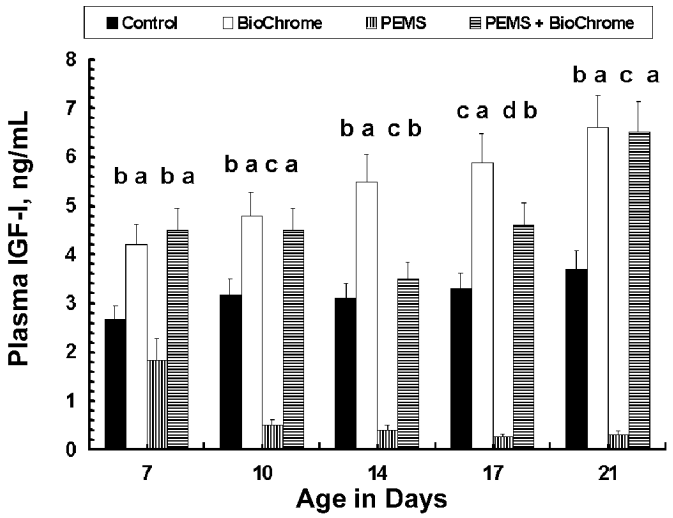

FIGURE 5. Time course of plasma insulin-like growth factor-I (IGF-I) responses for Control, BioChrome,® PEMS, and BioChrome®+PEMS treatment groups. Poults in the PEMS-exposed groups were given a single oral inoculation when they were 6 d of age. [a–d]Within days of age, significant differences ($P \leq 0.05$) among treatment groups are indicated by different lowercase letter headings.

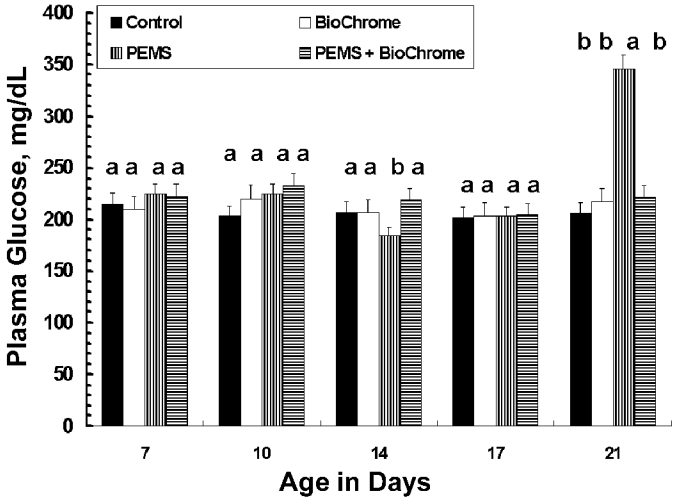

FIGURE 7. Time course of plasma glucose responses for Control, BioChrome,® PEMS, and BioChrome®+PEMS treatment groups. Poults in the PEMS-exposed groups were given a single oral inoculation when they were 6 d of age. [a,b]Within days of age, significant differences ($P \leq 0.05$) among treatment groups are indicated by different lowercase letter headings.

of BC, IGF levels increased in PEMS-infected poults comparable to noninfected levels. The increase in IGF in the BC-treated, PEMS-infected poults may account for the small but significant increase in BW in this group, because it has been shown that IGF function through insulin receptors (Rechler, 1985; Prosser, 1991; McMurtry et al., 1996, 1997). These observations support the hypothesis that BC in PEMS-infected poults sensitized insulin receptors, permitting the infected poults to develop a metabolic condition that could better sustain them during the stress response caused by the disease.

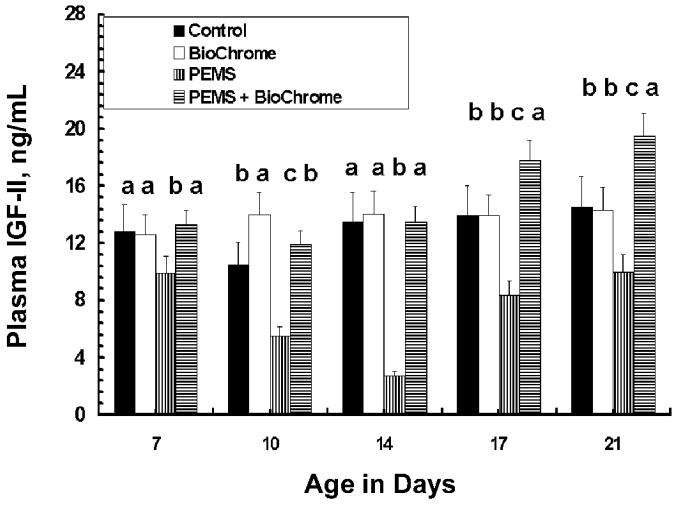

FIGURE 6. Time course of plasma insulin-like growth factor-II (IGF-II) responses for Control, BioChrome,® PEMS, and BioChrome®+PEMS treatment groups. Poults in the PEMS-exposed groups were given a single oral inoculation when they were 6 d of age. [a–c]Within days of age, significant differences ($P \leq 0.05$) among treatment groups are indicated by different lowercase letter headings.

Thyroid hormones have been reported to decrease significantly in PEMS-infected poults (Edens and Doerfler, 1997a,b; Doerfler et al., 1998); in this study T_4 and T_3 were decreased significantly by the infection. Nevertheless, in PEMS-infected poults with BC supplementation, both of these plasma hormones were elevated to levels significantly greater than the levels found in PEMS without BC. The most obvious effects of thyroid hormones in domestic fowl are the increases in the rate of oxygen utilization and basal heat production (Hendrich and Turner, 1967). The decrease in body temperature in PEMS, therefore, can be related directly to the hypothyrosis that normally occurs with this disease (Doerfler et al., 1998). In this study, the increase in plasma thyroid hormones in response to BC supplementation apparently resulted in a metabolic energy demand. Even though the PEMS-infected poults responded positively to the BC supplementation, BW were not corrected during the study.

Feed consumption during the peak of the PEMS infection (7 to 9 d after challenge) was reduced to approximately 25% of the control feed intake, which would further reduce the ameliorating effects of BC. This observation clearly indicated that there were different levels of BC intake in control vs. PEMS-infected poults. These data suggest that less BC can affect many of the metabolically active factors of this study. One could speculate that whether a fourfold increase in BC intake in the PEMS-infected poults during the peak of the disease might lessen the signs and effects of the disease.

The effects of BC in poultry species are not well documented, but poultry appear to respond in a manner similar to mammals. Specifically, BC appears to exert its effects through sensitization of insulin receptors and through its influence on glucose metabolism (Mooradian and Morley, 1987; Anderson, 1986, 1994). This mediation

TABLE 3. Influence of BioChrome® (BC) on hepatic glycogen and glucose-6-phosphatase activity in poult enteritis and mortality syndrome (PEMS)-infected 21-d-old female turkey poults[1]

Hepatic chemistry	Treatment groups			
Control	BC	PEMS	PEMS+BC	
Glycogen, mg/g liver	5.1 ± 0.3[a]	5.6 ± 0.2[a]	4.3 ± 0.3[b]	5.7 ± 0.4[a]
Glucose-6-phosphatase, mol P/min	24.0 ± 4.5[a]	23.7 ± 3.9[a]	6.5 ± 3.5[b]	19.1 ± 3.7[a]

[a,b]Within a row, means with unlike superscripts differ significantly ($P \leq 0.05$).

[1]n = 10 per observation.

of glucose metabolism in PEMS-infected poults appears to occur through stimulation of the thyroid hormones. Furthermore, Cr in mammals is recognized as an antistress agent (Mowat, 1994; Pagan et al., 1995; Mallard and Borgs, 1997) and, therefore, may have a potential role in the PEMS infection.

Nutritional interventions into the PEMS problem appear to have a potential that is greater than the use of antibiotics, which is important because many of the bacterial pathogens isolated from PEMS-infected poults are antibiotic resistant or develop resistance very rapidly. It is believed that the pathogens that cause PEMS also induce pathology via disruption of the normal biochemical and physiological mechanisms that establish the individual bird's homeostatic condition and subsequently contribute to its eventual demise. The lack of assimilation of nutrients and the inability to utilize the nutrients that are absorbed from the intestinal tract are two of the primary contributors to the mortality and lack of growth in PEMS-afflicted poults. Although there was only a small improvement in BW and FCR and no significant improvement in mortality for BC-fed, PEMS-infected poults, the data collected in these initial studies suggest that nutritional supplements may alleviate the intensity of the some of the symptoms of intestinal pathogenesis caused by bacterial or viral infection, may modulate the immune system, and may provide a stimulus to the metabolism of PEMS-afflicted poults.

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