ผลการเสริมแร่ธาตุกรดอมิโนเชิงซ้อนต่อการเจริญเติบโต ความหนาไขมัน ตะโพก การพัฒนาของกีบและองค์ประกอบทางเคมีของเลือดในม้ารุ่น

The Influence of Metal Amino Acid Complexs Supplementation on Growth, Croup Fat Thickness, Hoof Development, Bone Strength Indicators and Blood Chemistry of Growing Horses

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Abstract

Ten Thoroughbred growing horses (4 colts and 6 fillies) between one and two years of age were paired by both age and sex were used in a 240-d feeding trial to determine whether four metal amino acid complexes, MAAC (Fe 0.57, Zn 0.72, Cu 0.71 and Mn 0.14 mg/d) supplementation would alter growth, croup fat thickness, hoof development, bone strength indicators and blood chemistry of growing horses by top-dressed on the control 14.5% CP and 3.4 Mcal DE/kg commercial pelleted diet. The horses were assigned at random within breed and gender subgroups to one of two treatments : control diet and control diet with top - dressed MAAC (Zinpro Corporation Product, Eden Prairie, Mn. USA). The growing horses were weighed, measured for wither height, heart girth, body length, croup fat thickness by ultrasonic, hoof growth, bone strength indicators and blood chemistry analysis at the beginning and the end of experiment. Four MAAC supplementation had no effect on dry matter intake (DMI), but gain more ($P>0.05$) total weight gain, average daily gain (ADG) wither height, heart girth, body length and hoof growth, croup fat thickness, total of body fat and gain, percentage of body fat and gain and better ($P>0.05$) feed

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efficiency for growing horses fed the MAAC diet. Bone strength indicators, red blood cell (RBC), white blood cell (WBC), plasma protein and plasma mineral contents (Fe, Zn, Cn, Mn) showed increased (P<0.05) in the horses fed with MAAC, but decreased (P<0.05) in plasma protein, alkaline phosphatase (ALP), glutamic oxaloacetate transterase (GOT). Plasma glucose, creatinine and cholesterol were not influence by treatment (P>0.05). These results suggest that four trace minerals supplementation in the form of MAAC increase rate body fat, hoof growth, bone strength indicator, RBC, WBC and also plasma mineral contents (Fe, Zn, Cu, Mn) showed high efficiency of absorption revealed in increased in growth performance, hoof development, bone strength indicators, bone mineral composition on bone quality and also increase stress resistance levels in productivity and health status in growing horses.

Keywords: Blood chemistry, body fat, bone, growth, hoof, horses, mineral

บทคัดย่อ

ทำการศึกษาการเสริมแร่ธาตุเมตัลกรดอมิโนคอมเพล็กซ์ 4 ชนิด คือ เหล็ก (Fe) สังกะสี (Zn) ทองแดง (Cu) และแมงกานีส (Mn) ในอาหารม้ารุ่นพันธุ์โทโรเบรด อายุ 1 ถึง 2 ปี จำนวน 10 ตัว (เพศผู้ 4 ตัว เพศเมีย 6 ตัว) โดยมีอายุและเพศเท่ากันและมาจากสายเลือดเดียวกันเป็นเวลา 240 วัน โดยเสริมธาตุทั้ง 4 จาก MAAC (ผลิตภัณฑ์ของ Zinpro Coporation ประเทศสหรัฐอเมริกา) ลงไปในอาหารสำเร็จรูป (โปรตีน 14.5% พลังงานย่อยได้ 3.4 เมกาแคลอรี่/กก. อาหาร) ซึ่งมีเหล็ก 0.57, สังกะสี 0.72, ทองแดง 0.71 และแมงกานีส 0.14 มก./วัน เพื่อทดสอบผลการเจริญเติบโต, การสะสมไขมันในร่างกาย, การเจริญเติบโตของกีบ, ดัชนีความแข็งแรงของกระดูกและองค์ประกอบทางเคมีของเลือดในม้ารุ่น ทำการสุ่มม้ารุ่นเข้าการทดสอบ 2 กลุ่ม คือ กลุ่มควบคุมไม่เสริมแร่ธาตุและกลุ่มเสริมแร่ธาตุ 4 ชนิดจาก MAAC ลงไปในอาหารสำเร็จรูป ทำการบันทึกน้ำหนักตัว, ความสูง, ความยาว, ความหนาของลำตัว, ความหนาไขมันตะโพกด้วยเครื่องอัลตราโซนิค, การเจริญเติบโตของกีบและองค์ประกอบของเลือดที่เริ่มต้นและสิ้นสุดการทดลอง ผลการทดสอบครั้งนี้พบว่าการเสริมแร่ธาตุทั้ง 4 จาก MAAC นั้นมีผลทำให้แต่ไม่แตกต่างกันในทางสถิติ (P>0.05) ต่อปริมาณอาหารแห้งที่กินแต่มีการเพิ่มทั้งน้ำหนักตัวทั้งหมดอัตราการเจริญเติบโตต่อวัน ประสิทธิภาพการใช้อาหาร ความสูง, ความยาว, ความหนาของลำตัว, การงอกหรือการเจริญเติบโตของกีบและความหนาไขมันตะโพกของม้ารุ่นที่กินแร่ธาตุ MAAC มากกว่าม้ารุ่นที่กินสูตรอาหารควบคุม การทดลองครั้งนี้พบว่าการเสริมแร่ธาตุ MAAC ในอาหารม้ารุ่นจะมีผลทำให้ดัชนีความแข็งแรงของกระดูก จำนวนเม็ดเลือดแดง เม็ดเลือดขาวในเลือดและปริมาณแร่ธาตุ (Fe, Zn, Cu, Mn) ในพลาสม่าเพิ่มขึ้นและมีผลแตกต่างกับในทางสถิติ (P<0.05) เมื่อเปรียบเทียบกับม้ารุ่นที่กินอาหารควบคุมในทางตรงกันข้ามจะมีผลทำให้โปรตีนอัลคาไลน ฟอสฟาเตส (ALP) กลูตามิคออคซาโลอาซิเตททรานเพอเรส (GOT) ในพลาสม่าลดลง (P<0.05) สำหรับกลูโคส ครีเอทินินและคอเลสเตอรอลในพลาสม่านั้นพบว่าการเสริมหรือไม่เสริม MAAC จะให้ผลไม่แตกต่างกัน จากผลการทดลองครั้งนี้แสดงให้เห็นว่าการเสริมแร่ธาตุจาก MAAC ทั้ง 4 ชนิดในอาหารม้ารุ่นนั้นจะมีผลทำให้การดูดซึมแร่ธาตุมีประสิทธิภาพเพิ่มขึ้น ส่งผลทำให้สมรรถนะในการเจริญเติบโต การพัฒนาของกีบ ดัชนีความแข็งแรงของกระดูก ส่วนประกอบของแร่ธาตุในกระดูกซึ่งมีผลให้คุณภาพของกระดูกตลอดจนความสามารถในการต้านทานต่อความเครียดต่อสมรรถนะในการผลิตและรักษาสุขภาพในม้ารุ่นเพิ่มขึ้น

คำสำคัญ: กระดูก กีบ ไขมันในร่างกาย เจริญเติบโต ม้า แร่ธาตุ องค์ประกอบเคมีของเลือด

Introduction

Growth and skeletal development in horses are primarily functions of genetics and nutrient availability (Ott and Asquith (1989). Energy, protein, Ca and P all have been shown to influence skeletal development in growing horses (McLean and Urist, 1968; Hintz et al. 1971; Schryver et al., 1974; Ott et.al., 1979; Ott and Asquith, 1986). Trace minerals (TM) requirements of growing horses are a function of the size, age and growth rate of the horses (NRC, 1989; Ott and Asquith, 1995). Schryver et al. (1974) demonstrated tissue deposition of minerals in growing horses and suggested that requirements for each mineral were dictated by tissue accumulation, obligatory losses, and availability or deficiency of absorption of each mineral. Comparison of the TM content of typical, unsupplemented bermudagrass-based yearling diets with the requirements suggested by NRC (1989) reveal that several TM may be marginal or deficient. TM supplementation of yearlings using multimineral premixes has been shown to increase bone mineral deposition (Ott and Asquith , 1989 and 1995). Identifying with TM tested in the previous study, Fe, Mn, Zn, Cu, Co or I, or a combination of these minerals, is most critical to yearlings has not been completed. Cu and Zn are known to be directly involved in bone development and are often low in natural diets. Manganese deficiency cause decreased tibia length and breaking strength in lambs (Lassiter and Morton, 1968). Copper deficiency has been linked to cartilage abnormalities (Bridges et al. 1984; Carbery, 1984; Knight et al. 1985) in growing horses. Zinc deficiency in yearlings resulted in reduce growth, serum alkaline phosphatase and tissue Zn but did not affect bone Ca and P concentrations (Horrington et al., 1973). Knight et al. (1985) demonstrated a correlation between dietary Zn content of diets fed to growing horses and the incidence of observed skeletal abnormalities.

This study was to determine the effect of TM supplementation in the form of metal amino acid complexes (Zinpro Corporation; MN, USA) in growing horses on growth, hoof growth, total body fat and blood chemistry.

Materials and Methods

Ten thoroughbred growing horses raised at the Military Horse Research Center between one and two years of age were paired by both age and sex and assigned randomly to two treatments of five amimals (2 colts and 3 fillies) after stratification by body and sex. The horses were stabled at the Military Horse Station at Thapra, Khon Kaen Province. The horses were fed a control diet consist of a commercial pelleted 1 kg/hg/d, contained 14.5% CP and 3.40 Mcal DE/kg, paddy rice 3 kg/hd/d and fresh paragrass (*Brachiaria mutica*) *ad libitum*. The TM metal amino acid complexes, MAAC (consist of Fe 114, Zn 144, Cu 142.5

and Mn 28.5 mg/kg) was top-dressed on the morning commercial pelleted at a rate of 5 g/hd/d. Composition of commercial pelleted feed, paddy rice and paragrass nutrient composition are shown in Table 1. The horses were adapted to housing and the control experimental diet for 6 weeks and the experimental period was 240 days. The horses were individually fed two equal feedings at 0700 and 1600 for 1.5 hr feeding period of each meal. Water was provided to the house at all times. During the study, horses were housed in stalls that were 4x8 m or larger from 1630 until 0830 the next morning. All horses received a typical routine health care by Thai Military Horse Station, including vaccinations for encephalitis and rhinopneumonitis, tetanus and deworming at 60-d intervals prior to the study.

Growth and body measurement

All the start and termination of the experiment, the horses were weighed, measured for wither height, heart girth, body length (chest to point of buttocks). Hoof growth measurements were made every 60 d. The left and right front hooves of each horse were marked by a small hole made at the midline of the hoof 1 cm below the hair line at the coronet band using a farreir's drill. Hoof growth was determined by measuring the downward movement of this reference mark. Measuring the downward movement of this reference mark. Mean hoof growth was determined by pooling data from both fore hooves of each horse as described by Graham et al. (1994)

Bone strength indicators

Bone strength indicator of individual horse's cannon bone were taken as described by Loving and Johnston (1995) on d-1 and d-240 of the experiment. The formula to determine ideal circumference optimum bone strength indicators, the measurement of the cannon bone just below the knee should yield at least 7 inches or 17.78 cm circumference for every 1000 lb or 453 kg of body weight. Using these figures as guidelines, the ideal circumference of an individual horse's cannon bone can be determined according to the formula as shown below:

$$\frac{7inches}{1000lb} \times \text{body weight of horse} = \text{ideal circumference}$$

$$\frac{17.78cm}{453kg} \times \text{body weight of house} = \text{ideal circumference}$$

The left and the right house cannon bone were measured by pooling data from both fore legs of each horse. The body weight was used in calculating the ideal circumference bone strength indicators as described by Loving and Johnston (1995)

Ultrasonic croup fat measurement

Group or rump fat measurement were taken ultrasonically as described by Westervelt et al. (1976) and Graham et al. (1994) on d-1 and d-240 of the experiment. The regression

Table 1 Composition of commercial pelleted feed, paddy rice and paragrass (*Brachiaria mutica*)

Nutrient Composition	Commercial pelleted feed	Paddy rice	Paragrass	
			Fresh	Dry
Dry matter, %	87.90	90.00	26.54	88.00
GE, Mcal/kg	4.31	3.20	0.80	2.66
DE, Mcal/kg[a]	3.40	2.40	0.63	2.10
CP, %	14.50	6.00	2.72	9.02
EE,%	4.60	1.20	0.62	2.06
Ash,%	7.60	9.00	3.11	10.31
NFE,%	56.70	64.80	12.83	42.52
CF,%	4.50	9.00	7.26	24.07
Ca,%	1.02	0.45	0.08	0.27
P,%	0.78	0.05	0.04	0.46
Na,%	0.20	ND	ND	ND
Fe, mg/kg[b]	45	ND	14	46
Mn, mg/kg[b]	11	ND	12	38
Zn, mg/kg[b]	50	ND	5	16
Cu, mg/kg[b]	8	ND	ND	1
Co, mg/kg[b]	0.2	ND	ND	ND

[a] Calculated based on NRC (1978) and Glade (1984)
[b] Dry matter basis
ND = Not detech

equation derived by Westervelt et al. (1976) to determine body fat; Y = 8.64+4.70 X (r^2 = 0.86) (where Y = percentage of ether extractable fat and X = centimeters of rump fat) was used in this study to estimate percentage of body fat. The ultrasonic probe was placed approximately 5 cm lateral to the midline approximately one third of the distance from the point of the croup to the point of the tail. Three measurements were taken from each image on both the right and lift side of the midline. The mean of the six values was used in calculating the percentage of body fat. Fat gain during the experiment was calculated as the difference between estimated body fat at the completion of the experiment minus the initial estimated body fat at the start of the experiment as described by Graham et al. (1994).

Blood sampling and analysis

Blood samples were collected at the start and the end of the experiment by jugular puncture after morning and analyzed for red blood cells (RBC) and white blood cells (WBC). Plasma protein, glucose, choleslerol, creatinine concentrations and alkaline phos-phatase (ALP) and aspartate amino transferase (AAT or SGOT) activity were determined by commercial diagnostic laboratory (Khon Kean

Clinical Laboratory). Plasma mineral analysis were determined for Fe, Zn, Cu and Mn concentrations by flame atomic absorption spectrometry in the presence of lanthanum chloride on a Perkin Elmer Model 500 (Perkin-Elmer, Norwalk, CT).

Statistical Analysis

Statistical analysis of growth, body measurements and blood chemistry data were applied using the GLM procedure of SAS (1989) and difference between means were tested using Duncan's multiple range test. Differences were considered as significant when $P<0.05$ and trends were noted at a P-value of ≤ 0.10. Data shown as least square means with their associated standard error of mean (SEM).

Results and Discussion

Feed Intake, Growth and Feed Efficiency Response

Influence of four TM (Fe, Zn, Cu, Mn) of MAAC supplementation for the whole period of 240d on feed intake, growth and feed efficiency are shown in Table 4.2. Daily DM paragrass for growing horses fed MAAC diet consumed less than the growing horses fed with the control diet (8.44 vs 8.60) but gained more (difference were not significant, $P>0.05$) total weight gain (121.20 vs 108.96), average daily gain, ADG (0.50 vs 0.454), heart girth (21.04 vs 16.40), body length (15.78 vs 13.08), wither height (10.90 vs 8.38), and better feed efficiency (17.57 vs 19.964, feed DM/kg gain). The results from this study revealed that four TM of MAAC supplementation showed in increased total body weight gain 12.24 kg. for the whole period of testing 240 d Ott and Asquith (1989) reported that the need for TM supplementation in the diets of growing horses is a function of the animal's requirements for the mineral and the mineral content and alse bioavailability of the basal diet, and all four TM (Fe, Mn, Zn, Cu) have been shown to affect growth and skeletal development. Graham et al (1994) reported that girth gain in horses is highly correlated to weight gain (r = 0.98, Cunningham and Fowler, 1961). This high correlation allows girth gain to be an indicator of the growth and development of the animal. Thus it is common to estimate weight through the measurement of the heart girth when scale are not available. Although, yealing fed with four TM of MAAC showed greater weight gain and ADG but different were not significant ($P>0.05$) than yearlings fed the control diet. The difference in girth gain , body length gain and wither height gain between the two groups provided evidence that the weight gain response is real.

Hoof growth response

Hoof growth was improved by MAAC supplementation. Lawrence et al. (1987) has reported that elevated Fe intake (500 and 100 mg/kg diet) has a positive effect on bone mineralization in young ponies. The Cu-dependent enzyme lysyl oxidase is involved in the synthesis and maintenance of bone collagen and other connective tissue. Skeletal abnormalities occur in Cu-deficient. Foals consuming 9 mg Cu/kg of diet grew at normal rates, but cartilage lesion were detected in foals consuming diets containing 9 and 109 mg Cu/kg diet (Cupp and Howell, 1949). The results from this study also indicated that growing horses fed with four TM of MAAC gained more hoof growth than the growing horses fed the control no added TM diet (5.26 vs 4.76, P>0.05). No gross developmental abnormalities of hoof growth were detected in any of the animals (Table 2).

Bone strength indicators

Bone strength indicator of horse's cannon bone were taken by measured and by Loving and Johnson (1995) formula are shown in Table 3. Cannon bone yield by Loving and Johnson formula (1995) gained more cannon bone yield than cannon bone yield by measurment during the 240-d feeding trial in both initial and final measurement, but difference significant (P<0.05) was observed at the final measurement. Supplementation TM showed significant (P<0.05) greater bone strength indicator than the horses fed the control no added TM diet. Loving and Johson (1995) reported that at one time the skeletal maturity of a horse was estimated by radiographic assessment of closure of the growth plates, and by subjective evaluation of body growth and development. Recent research on athletic stress of young racehorses indicated that bone strength depends on more than growth plate closser. Bone strength depend on its cross-sectional area and bone mineral content. Cross-sectional area increases with skeletal maturity, especially if coupled with intelligent conditioning methods for a young horse. An increase in cross-sectional area logarithmically increases bone strength so it can ultimately sustain more stress. Measuring the cannon bone helps determine the horse's current structural strength. For optimal strength, the measurement of the cannon bone should yield at least 7 inches (17.78 cm) circumference for every 1000 lb (453 kg) of body weight. Using these figure as guidelines, the ideal circumference of horses from the initial of trial for both treatments by measurement were lower the optimal bone strength, but after the yearling consuming the TM supplementation for 240 d when measure at the termination showed greater increased (P<0.05) bone strength indicator than the yearling fed with the control no added the TM diet and also yield the optimal bone strength indicator when compared with the cannon bone yield by formula according the guidelines recommendation by Loving and Johnston (1995). These factors determine the ability of the bone to withstand stress and dictated by time.

Table 2 **Influence of metal amino acid complexes supplementation on growth, daily feed intake, feed efficiency and hoof growth**

Item	Treatment		SEM.
	Control diet	Control + TM*	
No. of observation	5	5	
Intake, dry matter, kg/d :			
Commercial pellet feed, DM basis	1.00	1.00	
Paragrass, DM basis	7.60	7.48	
Total	8.60	8.44	0.686
Weight, kg :			
Initial	306.22	306.06	32.657
Final	415.18	427.26	13.213
Total gain	108.96	121.20	23.620
ADG	0.454	0.505	0.098
Feed efficiency :			
Feed DM/kg gain	19.964	17.574	5.635
Heart girth, cm :			
Initial	149.00	148.54	2.012
Final	165.40	169.58	4.069
Gain	16.40	21.04	4.217
Body length, cm :			
Initial	135.06	135.34	3.218
Final	148.14	151.12	2.539
Gain	13.08	15.78	4.583
Wither height, cm :			
Initial	136.88	136.92	3.988
Final	145.26	147.82	1.828
Gain	8.38	10.90	3.784
Hoof growth, cm	4.76	5.26	0.539

TM* = MACC (Zinpro Corporation) consist of Fe 114, Zn 140, Cu 142.5 and Mn 28.5 mg/kg

DM = Dry matter

ADG = Average daily gain

Table 3 Influence of metal amino acid complexes supplementation on horse's cannon bone for bone strength indicators (the ideal circumference of the cannon bone)

Item	Treatment		SEM.
	Control diet	Control + TM*	
Initial wt, kg	306.22	306.06	32.657
Cannon bone yield by measure, cm	10.845	10.829	1.130
Cannon bone yield by formula, cm*	12.029	12.028	1.283
Difference, cm	−1.184	−1.199	0.185
Final wt, kg	415.18	427.26	13.213
Cannon bone yield by measure, cm	14.904[a]	16.402[b]	0.548
Cannon bone yield by formula, cm	16.317	16.791	0.519
Difference cm	+1.413[a]	+0.329[b]	0.171

[a-b] Mean within the same raw with no common superscripts are significant difference (P<0.05)

* Bone strength indicator formula = (17.78 ÷ 453) x body weight of horse = ideal circumstregth of the cannon bone for bone strength indicators (Loving and Johnson, 1995)

Fat measurement and blood analysis response

Fat measurements and blood analysis are shown in Table 4. Fat measurements were not affected by treatment (P>0.05) but there were trends with the growing horses fed with the four TM diet having more fat thickness, percentage of body fat, total body fat, total fat gain and percentage of total fat gain more than the horses fed the control no added TM. Growing horses fed the TM diet numerically higher value (P<0.05) on blood analysis (RBC and WBC) when compared with the horses fed the control no added TM. The results of this study are support the result of the previous study on young yearling that the TM supplementation in form of MAAC showed increase (P<0.05) in final RBC and WBC.

Plasma analysis response

Plasma analysis response are shown in Table 5. Growing horses fed the TM diet had numerically higher value (p<0.05) on plasma mineral contents (Fe, Zn, Cn, Mn) but numerically lower value (p<0.05) on plasma protein, alkaline phisphatase (ALP) and glutamic oxaloacetate transterase (GOT) Than the horses fed with the control no added TM disk. No difference wear observed on plasma slucere, creatinine and cholesterol by treatment (p>0.05). An increase in ALP is indicator of intestinal or alceletar damage had been repurtial by many researchers (Lewis, 1995). The results of this experiment are also support the results of the previous study on young yearling that multi-metal amino acid complexes trace mineral supplementation of uneven forage quality and stress for long-tern in young foals showed increased in plasma mineral contents which showed high availability or efficiency of absorption of minerals revealed in increased bone mineral deposition on bone quality when compared with the control foals group (Srisakorn et al., 2005). Hansen (1992) reported that two horses given the organic copper supplement demonstrated 36.4 and 58.3% increased in serum copper. Low blood levels are a common problem in cattle and horses in various parts of the world. A recent study with weaning horses can increase blood copper levels suffering from low blood copper by copper proteinate and mineral proteinate (Cu, Zn, Mn) have been made successfully in equine dials to improve structural soundness, increase stress resistance levels in performance horses and to reduce problem associated with developmental orthopedic disease in growing horses, increase foaling rates in broodmares and improve performance consistency in training horses (Vandergrift, 1992)

Table 4 **Influence of metal amino acid complexes supplementation on fat measurement and blood analysis**

Item	Treatment		SEM.
	Control diet	Control + TM*	
Initial fat :			
Thickness, cm	0.782	0.784	0.085
Body fat, %	12.316	12.326	0.401
Body fat, kg	37.882	37.806	5.250
Final fat :			
Thickness, cm	1.070	1.150	0.140
Body fat, %	13.670	14.046	0.659
Body fat, kg	56.810	60.072	4.453
Gain body fat, kg	18.928	22.266	5.604
Fat, % total gain	17.372	18.371	
Blood analysis:			
RBC, 10^6 cells/ml			
Initial	6.732	6.760	0.205
Final	6.700^b	8.096^a	0.186
WBC, 10^6 cells/ml			
Initial	8.354	8.386	0.141
Final	8.396^b	9.486^a	0.098

$^{a-b}$ Mean within the same raw with no common superscripts are significant difference (P<0.05)

Table 5 **Influence of metal amino acid complexes supplementation on plasma concentration of glucose, total protein, cholesterol, creatinine, alkaline phosphatase, aspartate amino acid transferase and minerals content (Fe, Zn, Cu, Mn) in growing horses**

Item	Treatment		SEM.
	Control diet	Control + TM*	
Plasma glucose, mg/dl :			
Initial	106.60	106.60	3.170
Final	111.80	111.40	5.074
Plasma protein, g/100ml :			
Initial	7.42	7.50	0.276
Final	6.68[a]	6.22[b]	0.258
Plasma cholesterol, mg/dl :			
Initial	100.00	97.60	18.779
Final	99.20	109.60	15.452
Plasma alkaline phosphatase, U/L :			
Initial	215.40	184.40	34.901
Final	163.00[a]	142.20[b]	11.983
Plasma glutamic oxaloautate tranforase U/L :			
Initial	339.80	326.40	48.031
Final	318.40[a]	255.20[b]	43.136
Plasma cratinine, mg/dl :			
Initial	1.940	1.600	0.396
Final	1.880	1.680	0.244
Plasma Fe, mg/L :			
Initial	1.181	1.191	0.020
Final	1.195[b]	1.491[a]	0.018
Plasma Zn, mg/L :			
Initial	0.489	0.487	0.012
Final	0.501[b]	0.669[a]	0.017
Plasma Cu, mg/L :			
Initial	0.805	0.802	0.018
Final	0.824[b]	0.948[a]	0.038
Plasma Mn, mg/L :			
Initial	0.213	0.208	0.016
Final	0.222[b]	0.367[a]	0.034

[a-b] Mean within the same raw with no common superscripts are significant difference ($P<0.05$)

Implications

The present findings confirm that feeding ingredients are freguently deficient in trace minerals in horses. It is common place to provide the four MAAC as special mineral supplements in the diets to know the bioavailability of each mineral source to meet the requirements of the horses. The increase in growth, feed efficiency, hoof growth, bone strength indicators, blood analysis (RBC and WBC) and plasma mineral contents (Fe, Zn, Cu, Mn) reflected on increase in horse productivity and health status of growing horses. This higher levels of performance suggest that there may be well metabolic and physiological benefits in addition to the effects of improved availability as minerals are involved in all aspects of the biological functions of the animal. However, further studies of MAAC supplementation in mares should be conducted, particularly in gestation and lactation barren mares.

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