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Mineral and vitamin interactions of steers in a Mediterranean climate

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Abstract

Liver, hair and plasma mineral levels and vitamins A and E levels in plasma were monitored in range steers throughout a complete year to study the interactions of minerals and these vitamins. Samples were taken from steers at two locations in Eastern Oregon, starting shortly after weaning and at four times during the year, which represented major feed changes. Half of the steers at each location received a commercial trace mineralized-salt mix and the other half received iodized salt (control). There was little correlation between mineral content of hair samples and levels in the liver or plasma. Significant positive correlations, however, were found between liver Se and with plasma Se, Cu and vitamin E; between liver Cu and both plasma Cu and liver Co; between liver Zn and liver Mn; between plasma vitamin E and plasma Zn; between liver Mn and both liver Co and plasma Zn; and between plasma Se and plasma Cu. Data also showed that sampling at a single time was not sufficient to establish mineral and vitamin status.

Key words: Steers; Minerals; Vitamin A, E; Interactions

1. Introduction

Copper (Cu) deficiency in beef cattle from different areas in Oregon has been suggested from plasma and liver Cu levels (Adams and Haag, 1957; Dent et al., 1956; Raleigh and Wallace, 1962) and from Cu and molybdenum (Mo) levels in feeds (Dent et al., 1956; Kubota et al., 1967). Eastern Oregon is considered ''variable'' regarding the selenium (Se) level of forages (Kubota and Allaway, 1972). Marginal zinc (Zn) deficiencies are considered a possibility in Oregon (Mayland, 1977; Mayland et al., 1980) but plants in Oregon appear to have adequate cobalt (Co) to protect grazing animals (Kubota, 1968). Because of this mediterranean climate, the forages range from a lushage green stage in the spring to very dry and of low quality by the end of the summer. The animals are then fed hay during the winter and this also results in variable vitamin A and E intake throughout the year. Previous work has indicated that the mineral status of cattle in Eastern Oregon varies markedly throughout the year (van Ryssen et al., 1991). This offered an opportunity to investigate the mineral and vitamin relationships under routine range conditions.

Although there is extensive information on some mineral interactions in large animals, limited data are

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available on the interactions of vitamins and minerals. The interactions of Cu and Zn, Mo and sulfur, and Mn and Zn have been well established (Mertz, 1987). Suggestions of a metabolic interaction between Se and Co in lambs have been presented (Wise et al., 1968). Vitamin E provided complete protection from muscle lesions produced by deficiencies of Cu, Co, and Zn in ducks (Van Vleet et al., 1981). The Mn, Zn and Cu levels in livers and kidneys were influenced by the Se and/or Se status of pigs (Ewan, 1971). A vitamin A and vitamin E-Se relationship was suggested in work with chicks (Combs, 1976), and a Cu, vitamin E and Se interaction was suggested in work with buffalo calves (Amer et al., 1985). Two proceedings are available on the interactions of dietary nutrients in animals (Bodwell and Erdman, 1988 and Levander and Cheng, 1980), but very little information was presented on large animals and none on range animals. The information in these proceedings was limited mostly to small animals. Since the mineral and vitamin intake varied throughout the year, the present work was conducted to obtain information on mineral and vitamin interactions of steers in a mediterranean climate. A secondary objective was to monitor mineral status on a year round basis using mineral content in liver biopsy samples, in both pigmented and white hair and in plasma. This information was used to calculate interactions among these variables.

2. Materials and methods

This investigation was conducted at the Eastern Oregon Agricultural Research Center which is at two locations: Burns (southeastern Oregon) and Union (northeastern Oregon). At Union with a higher elevation and greater precipitation during the summer, the grass becomes green earlier in spring and stays green longer in summer than at Burns. Burns has a typical "high desert" vegetation in summer. At both locations, cattle were fed harvested forages during winter and allowed to graze on range land at other times.

Twenty-two crossbred Hereford steers (four months old at Burns and five months at Union) were used at each site. At each location, one half (control) received iodized salt as a supplement and the other half a commercial trace mineralized salt (TM). Bone meal was provided on a free choice basis to all groups. The TM salt contained (g/kg) sodium chloride, 970–990; Zn, 3.5; Mn, 1.8; Mg, 3.7; Fe, 2.0; Cu, 3.5; Co, 0.06 and I, 0.10. At Union the steers also received selenium (25 mg/kg) as sodium selenite mixed with the TM salt, because prior work suggested low content of this element in forages at this location (Lanka and Vavra, 1982). The trial lasted from weaning in the fall through the end of the following summer period. During the winter the steers were pen-fed in groups according to treatment. Steers at Union were fed ad libitum a second cut, rain-damaged alfalfa hay and at Burns steers were fed meadow hay. During the other seasons the groups at each location grazed separate paddocks with the carrying capacities controlled to be comparable. At Union the steers grazed tall fescue (*Festuca arundinacea*) pasture during fall and on forested range the following spring and summer. The forested range consisted of grand fir (*Abies grandis*) forest on the north slopes, mixed conifer forest, wet meadow, and riparian. At Burns the steers grazed a meadow regrowth during the fall and grazed pure stands of crested wheatgrass (*Agropyron desertorum*) range during the spring and summer. The hay during the winter and forage in the fall consisted of about 75% of the biomass as rushes (*Juncus* spp.) and sedges (*Carex* spp.). The remaining 25% consisted of grass and shrub species. The salt and mineral mix were supplied free access in a loose form in mineral boxes to the steers.

The steers were weighed and plasma, liver biopsy (Bone, 1954), and pigmented and non-pigmented hair samples were taken at weaning (collection A) at the end of the fall grazing period (November, collection B); at the end of the winter (April, collection C) at the end of spring (July, collection D) and at the end of the summer grazing period (September, collection E). Newly grown hair was collected from the jaws and neck or in cases of lack of white hair the forehead (white hair) and side just behind the right shoulder (colored hair) each time blood or liver samples were collected. This was done by clipping the hair with coarse clippers and subsequently with a fine head clipper. The hair from the fine clippings was saved for analysis. The hair was soaked in water for 12 hours and washed 4 times with water followed by 2 washings with acetone on a suction flask, and acid digested with nitric and perchloric acids for mineral analysis.

A Jarrell Ash atomic absorption spectrophotometer (Model 82–516, Jarrell-Ash Company, Waltham, MA.) was used to measure Cu and Zn concentrations on diluted plasma samples and in livers after acid digestion. The Co level in the liver, Mo levels in liver and plasma, Mn in plasma and liver, and Zn, Cu, Mo, Mn and Co in hair digest were determined using a Perkin Elmer atomic absorption spectrophotometer (Model 3030 with a Zeeman background corrector, Perkin Elmer Corporation, Norwalk, CT) Plasma K levels were determined by flame photometry (Perkin Elmer flame photometer (Coleman 51 CA), Norwalk, CT). Selenium in the feed, tissues and hair was determined by a fluorometric procedure (Watkinson, 1966). A bovine liver reference standard (NBS) was used in all mineral analyses. The mineral content of liver and hair is expressed on a dry weight basis. The method of Chow and Omaye (1963) was used to determine vitamins A and E levels in plasma.

The data were analyzed separately for each location as a completely randomized design (two treatments) with five repeated measurements through the year (Gill, 1978). The two treatments were rarely different and the analyses were used only to obtain the proper standard errors to apply the Student-Newman-Keuls Procedure (Steel and Torrie, 1980) to evaluate the seasonal differences. Where necessary, to achieve homogeneity of variances, the data were subjected to logarithmic transformation. The correlations between the various parameters were on an intra-group (location, treatment and time of year) basis (Gill, 1978). Calculations of correlation coefficients were done with data collected at both locations.

3. Results

The mineral content of the diet and estimated mineral intakes of the steers from the salt and from the feed in this study have been presented (van Ryssen et al., 1991). The vitamin E content was about 200 mg/kg in the spring grass and 40 mg/kg in the hay after storage during the winter. The carotene content was about 80 mg/kg in the grass during the spring, but was 24 mg/kg in the hay after storage during the winter. The mineral content in the forages is known to vary throughout the year (van Ryssen et al., 1991) and the results of Tables 2 and 3 are consistent with variable dietary vitamins A and E throughout the year.

3.1. Minerals in liver and plasma

Copper. In Burns the Cu concentration in the livers (Fig. 1, top) decreased from weaning ($P<0.01$) at the end of fall to levels of between 10 and 20 μg/g liver during the other seasons with slight recovery in summer. The same trend was observed in plasma Cu levels (Fig. 1, bottom), although the lowest level was reached in winter with a subsequent increase thereafter to levels of 0.7 mg/l at the end of summer. Trace mineral supplementation did not have any consistent effect on plasma Cu levels, although in winter and spring, plasma Cu levels were significantly higher ($P<0.05$) in the group receiving the supplement than in the salt-fed group. At Union, liver Cu levels increased ($P<0.01$) during winter above those levels (10–20 mg/kg) observed at weaning and in the fall and spring. In summer, Cu levels increased again to above 25 mg/kg. Plasma Cu dropped from a level of 0.65 mg/l to between 0.45 and 0.55 mg/l in winter and spring and

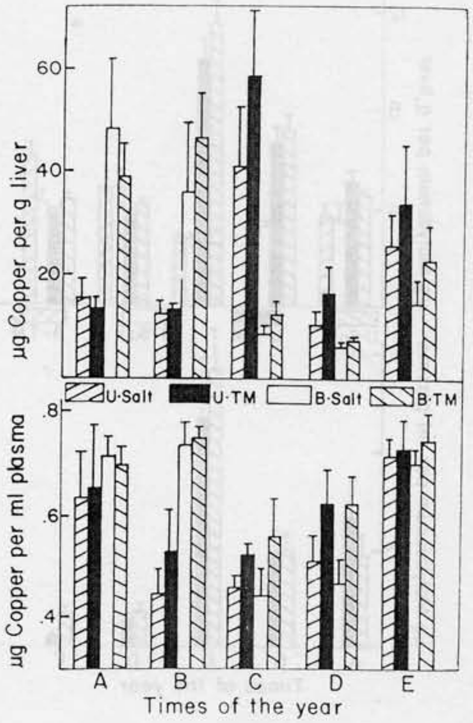

Fig. 1. Liver and plasma copper levels in steers at Union (U) and Burns (B) at weaning (A) and at the end of Fall (B), Winter (C), Spring (D) and Summer (E) when receiving a salt or a trace mineralized (TM) supplement. Vertical bars represent standard deviations.

increased again to 0.7 μg/ml in summer. The plasma and liver Cu concentrations did not show any statistically significant increase associated with the Cu supplement, except in the plasma of steers at Burns at the end of spring ($P<0.05$).

Molybdenum. Liver Mo levels at Burns (Fig. 2) remained fairly constant throughout the trial. Plasma Mo levels were not determined because of insufficient plasma sample size. At Union, plasma and hepatic Mo levels were higher ($P<0.01$) at the end of the winter feeding period than at any other time.

Selenium. At Burns, Se levels in the liver and plasma (Fig. 3) were higher at the end of fall ($P<0.05$) and winter ($P<0.01$) than at any other time. At Union, Se supplementation resulted in a significant ($P<0.01$) response in plasma and liver Se concentrations at all stages of the trial except at weaning. When no Se was given, the Se levels remained fairly constant at 0.2 mg/kg in the liver and 0.02 mg/l in plasma.

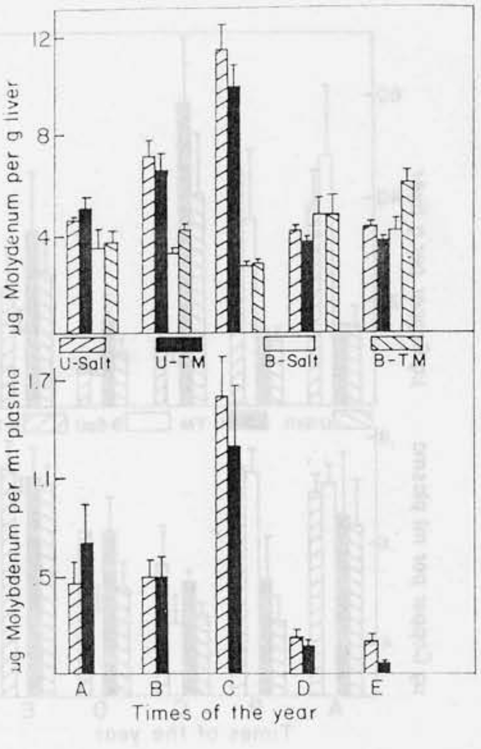

Fig. 2. Liver molybdenum levels in steers at Union (U) and Burns (B) and plasma molybdenum levels in steers at Union at weaning (A) and at the end of Fall (B), Winter (C), Spring (D) and Summer (E) when receiving a salt or a trace mineralized (TM) supplement. Vertical bars represent standard deviations.

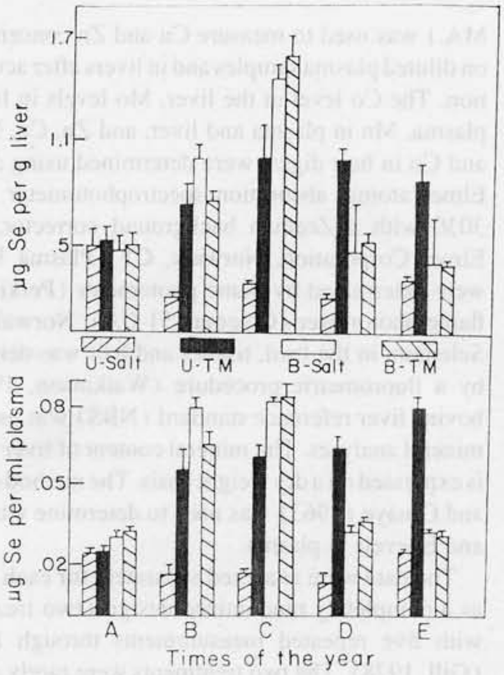

Fig. 3. Liver and plasma selenium levels in steers at Union (U) and Burns (B) at weaning (A) and at the end of Fall (B), Winter (C), Spring (D) and Summer (E) when receiving a salt or a trace mineralized (TM) supplement. Vertical bars represent standard deviations.

Zinc. At Burns and Union, hepatic Zn concentrations decreased after weaning and remained fairly constant (Fig. 4) at 80 to 90 mg/kg during the other seasons, with a slight increase at Burns at the end of summer. The trace mineral mix did not significantly influence ($P>0.05$) the liver Zn concentration at either location. Plasma Zn levels decreased after weaning with minimum levels observed at the end of fall at Burns and at the end of winter at Union. At the end of winter ($P<0.01$) and spring ($P<0.05$) the plasma Zn level was higher in the supplemented steers than in the control animals.

Cobalt. Except at weaning and at the end of summer, a significant ($P<0.01$) response was observed in Co concentration in the livers (Fig. 5) at Burns due to supplementation with the trace mineral mix. At Union, Co levels in the liver stayed relatively constant throughout the experimental period with no difference between the salt mix and the trace mineral supplement fed groups.

Potassium. Neither the season of the year nor the

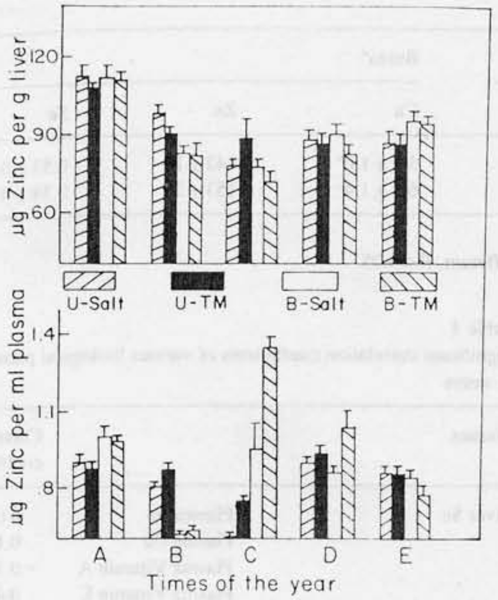

Fig. 4. Liver and plasma zinc levels in steers at Union (U) and Burns (B) at weaning (A) and at the end of Fall (B), Winter (C), Spring (D) and Summer (E) when receiving a salt or trace mineralized (TM) supplement. Vertical bars represent standard deviations.

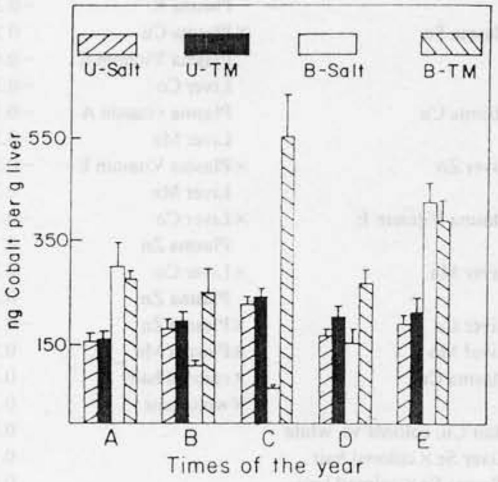

Fig. 5. Liver cobalt levels in steers at Union (U) and Burns (B) at weaning (A) and at the end of Fall (B), Winter (C), Spring (D) and Summer (E) when receiving a salt or a trace mineralized (TM) supplement. Vertical bars represent standard deviations.

grazing location affected the plasma potassium (K) levels (data not shown). The average values ranged from 185 to 231 μg mg K per ml plasma.

Manganese. Neither the season of the year nor the grazing location affected the liver and plasma Mn levels (data not shown). The average hepatic Mn levels ranged from 6.9 to 9.9 ng per g liver (dry basis), and average plasma Mn levels ranged from 3.4 to 5.0 ng per ml.

3.2. Minerals in hair

Although Zn, Cu, Se, Mo, Mn and Co were determined in hair, only the Cu, Zn, and Se levels are presented to indicate the difficulty involved in assessing mineral status by this method (Table 1). Cu levels were significantly higher in the white hair than the colored, but in contrast the Se levels were higher in the colored hair. There were no significant correlations between hair levels of Zn, Cu, Se, Mo, Mn or Co with the content of these minerals in the liver or plasma, except for plasma Cu and liver and plasma Se.

3.3. Vitamins A and E

The concentration of vitamin E in plasma (Table 2) was lower at the end of the fall and winter ($P<0.05$ to 0.01) than during the other seasons at Union. In contrast, the vitamin E levels in cattle at Burns were lower at the end of the fall grazing period than at any other time. However, consistent with the cattle at Union, the plasma vitamin E levels were lower at the end of summer ($P<0.05$) than at the end of spring.

Significant variations in plasma vitamin A levels were also observed throughout the year (Table 3). The lowest values at both locations were at the end of the winter period, which was significantly less ($P<0.01$) than at the end of spring grazing. These values were even less than those at weaning ($P<0.05$). The fluctuations of plasma vitamin A, however, were not as great as for vitamin E.

3.4. Interactions

Table 4 shows the significant intra-group correlations where time, treatment and location effects have been eliminated. Of the many biological parameters studied, only the statistically significant correlations are shown. There were positive correlations between liver Se and plasma Se; plasma Cu and plasma vitamin E; liver Cu with both plasma Cu and liver Co; plasma Se and plasma Cu; liver Zn and liver Mn; plasma vitamin E and plasma Zn; liver Mn with both hepatic Co and plasma Zn; liver Mo with plasma Mo; plasma Cu with the Cu content of both colored and white hair; the Cu

Table 1

Average mineral concentration of colored versus white hair from steers

Hair color	Union[a]			Burns[a]		
	Cu	Zn	Se	Cu	Zn	Se
Colored	5.1 ± 1.2^{b}	129 ± 15	0.34 ± 0.17^{b}	5.1 ± 1.0^{b}	142 ± 14	0.53 ± 0.31^{b}
White	6.5 ± 1.2^{c}	148 ± 19	0.24 ± 0.11^{c}	6.3 ± 1.4^{c}	153 ± 21	0.34 ± 0.18^{c}

[a] Values ($\mu g/g$) are means ± Standard Deviations.

[b,c] Mean values within columns with different superscripts are significantly different, $P < 0.05$.

Table 2

Plasma concentration of Vitamin E of steers at Union and Burns during different times of the year

Vitamin E ($\mu g/ml$)[a]

Seasons	Union		Burns	
	Salt	TM[b]	Salt	TM[b]
Weaning	7.8 ± 2.2^{c}	8.3 ± 2.3^{f}	$7.5 \pm 2.5^{c,e}$	$7.1 \pm 1.4^{c,f}$
Fall	$3.8 \pm 1.0^{c,f}$	$3.8 \pm 0.8^{d,e}$	4.2 ± 0.9^{f}	4.8 ± 0.9^{e}
Winter	$1.8 \pm 0.7^{d,f}$	$1.4 \pm 0.3^{c,e}$	5.3 ± 1.3^{f}	5.8 ± 1.0^{e}
Spring	8.7 ± 2.9^{e}	8.8 ± 2.1^{f}	$11.5 \pm 3.1^{d,e}$	$10.2 \pm 3.5^{d,f}$
Summer	7.7 ± 1.8^{e}	8.4 ± 2.6^{f}	5.1 ± 0.9^{f}	5.4 ± 0.8^{e}

[a] Values are means ± standard deviations.

[b] TM = Trace mineralized salt.

Values within columns with different superscripts are significantly different. $^{c,d}P < 0.05$; $^{e,f}P < 0.01$.

Table 3

Plasma vitamin A concentration in steers at Union and Burns at different stages of the trial

Vitamin A ($\mu g/ml$)[a]

Seasons	Union		Burns	
	Salt	TM[b]	Salt	TM[b]
Weaning	$0.79 \pm 0.06^{c,e}$	$0.82 \pm 0.11^{c,e}$	$0.88 \pm 0.11^{d,e}$	0.85 ± 0.12^{e}
Fall	$1.20 \pm 0.17^{d,f}$	1.11 ± 0.14^{f}	$0.87 \pm 0.19^{d,e}$	0.80 ± 0.18^{e}
Winter	$0.83 \pm 0.20^{c,e}$	$0.87 \pm 0.12^{c,e}$	$0.62 \pm 0.11^{c,e}$	0.59 ± 0.10^{f}
Spring	$1.09 \pm 0.23^{d,f}$	1.18 ± 0.13^{f}	1.28 ± 0.25^{f}	0.95 ± 0.24^{e}
Summer	0.98 ± 0.19^{d}	$1.07 \pm 0.25^{d,f}$	0.79 ± 0.09^{d}	0.85 ± 0.15^{e}

[a] Values are means ± standard deviations.

[b] TM = Trace mineralized salt.

Values within columns with different superscripts are significantly different. $^{c,d}P < 0.05$; $^{e,f}P < 0.01$.

Table 4

Significant correlation coefficients of various biological parameters in steers

Tissues		Correlation coefficient[a]
Liver Se	× Plasma Se	0.86**
	Plasma Cu	0.18*
	Plasma Vitamin A	−0.30**
	Plasma Vitamin E	0.48**
	Liver Co	−0.21*
Liver Cu	× Plasma Cu	0.38**
	Plasma Vitamin E	−0.34**
	Liver Co	0.22*
	Plasma Zn	−0.32**
	Plasma K	−0.23*
Plasma Se	× Plasma Cu	0.22*
	Plasma Vitamin E	−0.45**
	Liver Co	−0.23**
Plasma Cu	Plasma vitamin A	−0.16*
	Liver Mn	−0.22*
Liver Zn	× Plasma Vitamin E	−0.20*
	Liver Mn	0.24**
Plasma Vitamin E	× Liver Co	−0.32**
	Plasma Zn	0.19*
Liver Mn	× Liver Co	0.23**
	Plasma Zn	0.20*
Liver Co	× Plasma Zn	−0.17*
Liver Mo	× Plasma Mo	0.59**
Plasma Cu	× colored hair	0.28*
	× white hair	0.23*
Hair Cu, colored vs. white		0.89**
Liver Se × colored hair		0.19*
Plasma Se × colored hair		0.21*
Hair Se, colored vs. white		0.82**
Hair Co, colored vs. white		0.57**
Hair Zn, colored vs. white		0.25**

[a] Adjusted for group differences where the mean shifts were taken out.

$^{*}P < 0.05$.

$^{**}P < 0.01$

content of colored versus white hair; liver and plasma Se levels with colored hair; and Co and Zn in colored and white hair. There were negative correlations between liver Se and both plasma vitamin A and liver Co; liver Cu with plasma vitamin E, Zn, and K; plasma Se with both plasma vitamin E and liver Co; plasma Cu with both plasma vitamin A and liver Mn; liver Zn with plasma vitamin E; plasma vitamin E with liver Co; and liver Co with plasma Zn.

4. Discussion

4.1. Copper and molybdenum

The dietary Cu requirements for beef cattle have been estimated to range from 4 to 10 mg/kg (NRC, 1984; Suttle, 1983). Although forage levels of Cu are helpful, hepatic and plasma levels are more useful. Hepatic Cu concentrations (DM) below 20 mg/kg (Miller, 1979) or 25 mg/kg (McDowell et al., 1983) have been suggested as indicative of Cu deficiency in growing cattle, but other work revealed that grazing livestock with hepatic Cu levels ranging from 8 to 32 mg/kg showed no clinical signs of Cu deficiency (Suttle, 1986). There is no explanation for the high level of Cu in the livers of both groups at Union in winter but this could be a "systemic effect" due to the Cu × Mo × S interaction at high Mo intakes, but plasma Cu levels would also have been expected to be high (van Ryssen and Stielau, 1981).

4.2. Selenium and vitamins A and E

The NRC recommended a concentration of 0.20 mg/kg (NRC, 1984) as the minimum Se required by beef cattle while McDowell et al. (1983) proposed a level of 0.1 mg Se/kg feed. The control group at Union had plasma Se levels below 0.03 mg/l and the liver Se fluctuated close to 0.25 mg/kg, considered critical by McDowell et al., (1983). At Burns the plasma and liver Se content remained above the critical level but during spring and summer there was a drop in the plasma and liver Se levels in the steers. Plasma vitamin E in the steers at Union was low during fall and winter, coinciding with the low Se concentrations in plasma and liver. The plasma vitamin A concentrations were not affected by the various seasons as much as plasma vitamin E in the present study.

4.3. Interactions

The interactions of Cu and Zn, Cu, Mo and Sulfur, Mn and Co, and Mn and Zn have been studied extensively (Mertz, 1987). The other interactions identified in Table 4 have been less characterized. Co was significantly lower in kidneys of Se deficient lambs in comparison to normal animals (Wise et al., 1968), suggesting a metabolic relationship between Se and Co. This is consistent with our data showing a significant correlation of both hepatic and plasma Se with liver Co. Complete protection from muscle lesions produced by deficiencies of Cu, Co, and Zn in ducks was provided by vitamin E (Van Vleet et al., 1981), which is consistent with our data showing a relationship of plasma vitamin E with liver Co and plasma Zn, and liver Zn with plasma vitamin E. The Mn content was significantly increased in livers and kidneys of pigs fed vitamin E or Se, and Zn and Cu significantly decreased in kidney when vitamin E was fed (Ewan, 1971). This is consistent with the present results showing a relationship between hepatic copper and zinc with plasma vitamin E. The interactions of zinc and vitamin E are in agreement with the work with chicks and rats (Lonnerdal, 1988). In a vitamin A and vitamin E-Se relationship study with chicks, vitamin E-Se deficiency was alleviated with high levels of vitamin A (Combs, 1976). In ligated intestinal loops, high dietary vitamin A promoted the absorption of Se but interfered with the absorption of vitamin E. A relationship between hepatic Se and plasma vitamin A in our study is consistent with these observations. Complex interrelationships were also demonstrated with buffalo calves where plasma Cu decreased after Se administration but increased in comparison to controls after Se plus vitamin E administration (Amer et al., 1985). The interaction of liver Se and plasma copper, and hepatic Cu with plasma vitamin E with our steer study is in agreement with these observations. Review of the literature did not reveal any information on interaction of plasma K with liver Cu, plasma Cu with liver Mn or liver Co with plasma Zn. Thus, more research is needed on nutrient interactions, particularly in large animals.

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Résumé

van Ryssen, J.B.J., Whanger, P.D., Turner, H.A. et Tinsley, I.J., 1994. Interactions des vitamins et oligo-elements chez les bouvillons dans une climat mediterranée. *Livest. Prod. Sci.*, 38: 107–115.

Dans le cadre d'une étude sur l'interaction entre les vitamines A et E et les oligo-éléments chez les bouvillons sur parcours, on a surveillé pendant une année complète le niveau de ces vitamines dans le plasma, ainsi que le niveau des oligo-éléments dans le foie, le poil et le plasma d'une population. On a prélevé des échantillons sur des bouvillons de deux localités de l'est de l'Orégon, en commençant peu après le sevrage et quatre fois par an, ce qui correspond aux principaux cycles alimentaires. Dans chaque localité, on a administré un mélange d'oligo-éléments et de sel en préparation commerciale à la moitié des animaux; on a administre du sel iodé à la deuxiéme moitié (groupe témoin). L'étude a révélé une très faible corrélation entre la teneur en oligo-éléments dans le poil et dans le foie ou le plasma. Elle a toutefois mis en évidence des corrélations positives tefruficatives entre le Se hépatique et le Se, le Cu et la vitamine E plasmatiques; entre le Cu hépatique et le Cu plasmatique d'une part, le Co du hépatique d'autre part; entre le Zn et le Mn hépatiques; entre le vitamine E et le Zn plasmatique; entre le Mn hépatique et le Co hépatique d'une part, le Zn plasmatique d'autre part et entre le Se et le Cu plasmatiques. Les données ont également mis en évidence le fait qu'un seul échantillonnage, sans échelonnement dans le temps, ne suffit pas pour déterminer l'état minéral et des vitaminaque.

Kurzfassung

van Ryssen, J.B.J., Whanger, P.D., Turner, H.A. und Tinsley, I.J., 1994. Wechselbeziehungen zwischen Mineralstoffen und Vitaminen von Bullen im mediteranen Klima. *Livest. Prod. Sci.*, 38: 107–115.

Der Gehalt an Mineralstoffen in der Leber, den Haaren und dem Plasma und der Gehalt an Vitamin A und E im Plasma wurde an Bullen während eines ganzen Jahres bestimmt, im die Wechselwirkungen zwischen Mineralstoffen und den Vitaminen zu untersuchen. Es wurden zwei Stichproben von Bullen in zwei Orten im östlichen Oregon einbezogen. Die Untersuchungen begannen kurz nach dem Absetzen und wurden viermal im Jahr durchgeführt, wodurch die größten Veränderungen in der Fütterung erfaßt wurden. Die eine Hälfte der Bullen in jedem Ort erhielt eine kommerzielle Mineralsalzmischung, während der anderen jodiertes Salz verabreicht wurde. Die Korrelation zwischen dem Mineralstoffgehalt der Haare und der Leber bzw. des Plasmas war gering. Signifikante positive Korrelationen wurden jedoch zwischen dem Se der Leber und dem Plasma sowie auch beim Cu und dem Vitamin E gefunden. Weitere signifikante Korrelationen wurden zwischen Leber Cu und Plasma Cu sowie Leber Co; zwischen Leber Zn und Leber Mn; zwischen Plasma Vitamin E und Plasma Zn; zwischen Leber Mn und Leber Co sowie Plasma Zn und zwischen Plasma Se und Plasma Cu gefunden. Die Ergebnisse zeigen, daß eine Stichprobe zu einem Zeitraum nicht ausreicht, den Vitamin- und Mineralstoffstatus einzuschätzen.

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