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Upper Midwest Beef Cow Mineral-Vitamin Nutrition

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Adequate mineral-vitamin nutrition is vital in optimizing animal growth, lactation, reproductive function and immune response. As Figure 1 illustrates, clinical signs of mineral deficiencies may be obvious only after the mineral status of the animal has dropped below threshold levels that may have affected response to vaccination, immunity to disease and parasite challenges, growth and fertility.

MINERALS

At least 17 minerals are required by beef cattle. They are classified as macro-nutrients (required in large amounts) or as micronutrients (small amounts). Many of the essential minerals are found in sufficient concentrations in common feedstuffs. Other minerals are frequently insufficient in diets fed to cattle, and supplementation is necessary to optimize animal performance and health.

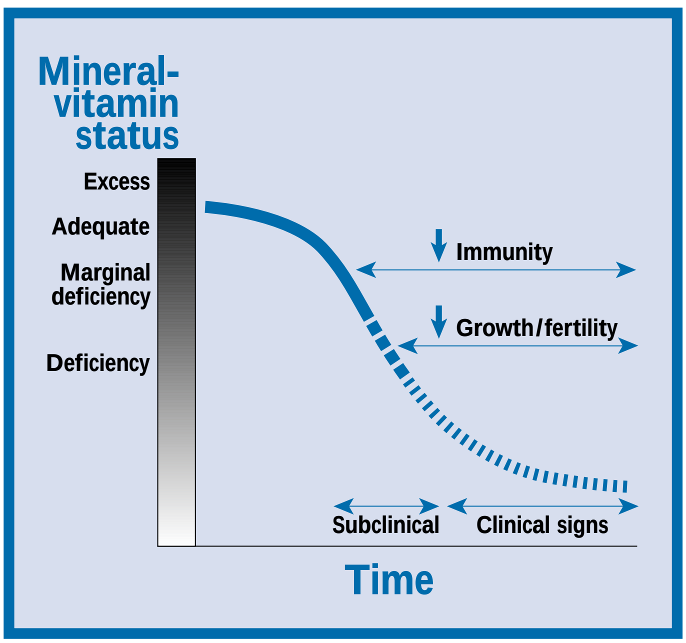


Figure 1. Effects of mineral-vitamin deficiencies on cow-calf production (adapted from Wikse, 1992).

Macrominerals

Macrominerals are nutrients required daily in relatively large amounts (grams): calcium (Ca), chlorine (Cl), magnesium (Mg), phosphorus (P), potassium (K), sodium (Na) and sulfur (S).

Ca

Calcium is the most abundant mineral in the body. Approximately 98 percent of calcium functions as a structural component of bones and teeth. The remainder is involved in vital functions such as blood clotting, membrane permeability, muscle contraction, transmission of nerve impulses, cardiac regulation, secretion of hormones, and activation and stabilization of enzymes.

Forages are generally good sources of calcium, and legumes have a higher content than grasses. Cereal grains are low in calcium. Therefore, high- grain diets often need additional calcium supplementation.

Chlorine is the major anion in fluid outside of cells. Chlorine, sodium and potassium are involved in maintaining water and acid-base balance. Chlorine is necessary for the formation of hydrochloric acid in gastric juice and for the activation of amylase.

Chlorine requirements are not well defined, but a deficiency is not likely under most conditions because chlorine requirements are normally met by feeding salt (NaCl).

Trace mineral soil deficiencies of cobalt, copper, iodine, manganese and selenium are common in the upper Midwest, making supplementation imperative in meeting animal nutrient requirements.

More than 300 enzymes are known to be activated by magnesium, which is essential for all biosynthetic processes, including glucose utilization, membrane transport and the transmission of genetic code. Magnesium is also involved in bone health and transmission of impulses across nerve and muscle membranes.

Grass tetany is characterized by low magnesium concentrations in plasma and cerebrospinal fluid and is most common in lactating cows grazing lush spring pastures or fed harvested forages low in magnesium. In early spring pastures, low magnesium availability is the primary cause of grass tetany. Fertilizing pastures with high amounts of nitrogen and potassium may increase the incidence of the problem. Spring supplementation of “Mag Ox” (magnesium oxide, MgO) can reduce the potential for grass tetany.

Approximately 80 percent of phosphorus in the body functions with calcium as a structural component of bones and teeth. Phosphorus also functions in cell growth and differentiation as a component of DNA and RNA, and in energy utilization and transfer, phospholipid formation and maintenance of acid-base balance. Phosphorus is required by ruminal microorganisms for their growth and metabolism.

Potassium is the major cation inside cells. It is important in acid-base balance, regulation of osmotic pressure, water balance, muscle contractions, nerve impulse transmission and enzyme reactions.

Forages and oilseed meals are good sources of potassium, but cereal grains are often deficient. Therefore, high-concentrate diets may require potassium supplementation unless a high-potassium forage or protein supplement is included in the diet.

Sodium is the major cation outside of cells. Sodium is involved in maintaining water and acid-base balance. Sodium also functions in muscle contractions, nerve impulse transmission, and glucose and amino acid transport.

Ruminants often have an appetite for sodium, and if salt is provided free-choice, they will consume more than they require.

Sulfur is found in feedstuffs largely as a component of protein. It is a component of the amino acids methionine, cysteine and cystine. Sulfur is also a component of the B vitamins thiamin and biotin. Sulfate functions in detoxification reactions in the body. Ruminal microorganisms require sulfur for their growth and normal metabolism.

Cattle grazing sorghum forages may have an increased sulfur need because of the demand for sulfur in the detoxification of hydrocyanic acid (prussic acid) and the low sulfur content in these forages.

Microminerals

Microminerals or trace minerals are nutrients required daily in small amounts (milligrams): cobalt (Co), copper (Cu), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se) and zinc (Zn). Some elements — such as chromium (Cr) and nickel (Ni) — may be required in ultra trace amounts (micrograms).

Cr Chromium is believed to function as a component of the glucose tolerance factor, which may potentiate the action of insulin. Although some studies have shown an increased immune response and growth when chromium was supplemented to stressed cattle, the information is not sufficient to determine if cattle have a chromium requirement.

Co Ruminants have a requirement for vitamin B_{12} rather than cobalt. Microorganisms in the rumen utilize cobalt to synthesize vitamin B_{12}, which the animal absorbs and uses. Vitamin B_{12} is a component of a liver enzyme that metabolizes propionate, a volatile fatty acid produced in the rumen.

Cu Copper is an essential component of a number of enzyme reactions. It is important for collagen, prostaglandin and elastin formation. It plays a role in energy transfer in the cell and is also involved in protecting the body from oxidation. Copper is essential for iron utilization, influencing hemoglobin formation and oxygen-carrying capacity.

The trace elements molybdenum, zinc, iron and sulfur are antagonists of copper, resulting in reduced copper availability when they are consumed in an inappropriate ratio to copper. Dietary concentrations of 400 ppm iron or 3 ppm molybdenum can induce copper deficiency.

I The primary role of iodine is the synthesis of thyroxine and triiodothyronine hormones by the thyroid gland. Thyroid gland hormones actively regulate energy metabolism, thermo-regulation, reproduction, growth and development, circulation and muscle formation.

Fe More than 50 percent of the iron in the body is present in hemoglobin. It is also an essential component of a number of proteins involved in oxygen transport and utilization. Several enzymes either contain iron or are activated by it.

In areas where drinking water or forages are high in iron, dietary copper may need to be increased to prevent copper deficiency.

Mn Manganese is involved in a number of enzyme systems in the body that participate in carbohydrate, fat and protein utilization. It is also involved in bone development and maintenance. Manganese contributes to functioning of the reproductive process in both males and females.

Although manganese is abundant in forages, it is generally low in grains. The body has only limited storage reserves, and absorption of manganese by livestock is poor.

Mo Molybdenum functions as an essential component of several enzyme systems, but its level of dietary requirement for cattle has not been established.

Dietary molybdenum concentrations as low as 5 ppm have been shown to induce copper deficiency. High soil molybdenum occurs in much of the southwestern United States, but molybdenum toxicity does not appear to be a common problem in the upper Midwest.

Ni The function of nickel in mammalian metabolism is unknown, although nickel deficiency can be experimentally induced in rodents. Research data are insufficient to determine nickel requirements for beef cattle.

Se Selenium, in its role in the enzyme glutathione peroxidase, protects tissues and membranes from oxidant damage. It also has a role in thyroid enzyme function. Selenium works in coordination with vitamin E but cannot substitute for it. A diet low in vitamin E may increase the amount of selenium needed to prevent abnormalities such as nutritional muscular dystrophy (white muscle disease).

The upper Midwest and the Northeast regions of the United States are selenium-deficient. Recommended selenium supplementation rates for these selenium-deficient areas are at or near the maximum level allowed by the FDA. The 1997 FDA-approved maximum selenium supplementation rates with sodium selenate or sodium selenite for beef cattle are:

- 0.3 ppm in complete feeds.
- 3 mg/day for cattle fed limited supplement.
- 120 ppm in free-choice salt mineral mixes with a maximum of 3 mg Se/day.

For mineral-vitamin free-choice mixes, the most restrictive of these regulations is the limit of 3 mg/animal/day. Assuming a daily intake of mineral mix for an individual animal is 0.15 or 0.25 lb, maximal legal selenium concentration in the mix would be 44 and 26 ppm, respectively.

Photo Courtesy Limousin World

Zinc is a component of enzymes that participate in nucleic acid, carbohydrate and protein metabolism. It is required for proper immune function, appetite, growth, and sexual development and function, and it functions in wound healing.

VITAMINS

The most necessary vitamin supplementation for ruminants provides the fat-soluble vitamins A and E. The fat-soluble vitamin K and water-soluble B vitamins are abundant in many feeds and are synthesized by ruminal microorganisms. Therefore, their supplementation is generally not required.

Vitamin A is a required component of visual pigment and is necessary for growth, reproduction, maintenance of epithelial tissues and bone development. Vitamin A may also aid in protection against disease.

Precursors of vitamin A occur in plant material (carotenes or carotenoids) in several forms and are converted to vitamin A by cattle. Few grains except yellow corn contain significant amounts of carotenoids. High quality forages provide carotenoids in large amounts but tend to be seasonal in availability. Carotenes are rapidly destroyed by exposure to sunlight and air, especially at high temperatures. Potential vitamin A supply from hay decreases as storage time increases.

Vitamin D is required for calcium and phosphorus absorption, normal mineralization of bone and mobilization of calcium from bone. A regulatory role in immune cell function has also been suggested for vitamin D.

Ruminants do not store appreciable amounts of vitamin D. However, because vitamin D is synthesized by beef cattle exposed to sunlight or fed sun-cured forages, they rarely require vitamin D supplementation.

Vitamin E functions as an antioxidant and is involved in the maintenance of structural integrity of muscle and the vascular system. Vitamin E is also needed for the uptake and storage of vitamin A.

Vitamin E is required by beef cattle, but the amount required daily for optimum health is not known. Determining vitamin E requirements is difficult because of this vitamin's interrelationships with dietary concentrations of antioxidants, sulfur-containing amino acids and selenium. Vitamin E has also been fed at pharmacological concentrations to provide increased beef product shelf life.

Vitamin K is required for the synthesis of several blood clotting factors. It is abundant in pasture and green roughages and is synthesized by ruminal microorganisms. Therefore, supplementation of vitamin K is generally not required. Deficiency of vitamin K can be caused by ingestion of dicoumarol as seen in "sweet clover disease" syndrome. Dicoumarol is a vitamin K antagonist formed by fungi in improperly cured sweet clover hay. Consumption of dicoumarol leads to prolonged blood clotting times and may cause death from uncontrolled hemorrhages.

Formulation of a mineral-vitamin supplement

Table 1 provides an example of a mineral-vitamin mix and how it compares with the beef cow's requirements. A similar mix has been used at Michigan State University's Lake City Experiment Station since 1988. It is well known that the mineral and vitamin content of feedstuffs can vary greatly. Likewise, there is considerable variation in mineral-vitamin consumption among animals. Therefore, conservative estimates of nutrient intake and liberal estimates of requirements were made. The mix in Table 1 is formulated for cattle consuming at least 25 lb of average quality hay typical of the upper Midwest. Nutrient requirements are based on those for a lactating beef cow at peak lactation (about six weeks postcalving). This table assumes that average supplement intake is .17 lb per day. The soy or coconut oil is added to the mix to reduce dust and prevent separation of the ingredients. Sweetening agents are added to offset bitter flavors, especially from magnesium oxide.

Management considerations

When selecting a commercially manufactured supplement mix, it is important to note not only the concentration of minerals but also their source. Mineral sources vary in bioavailability, or how much of the mineral can be absorbed and utilized. For example, copper sulfate is well utilized by cattle, whereas copper oxide has nearly zero availability. Various sources and their relative bioavailability are given in Table 2 for comparison. Be sure to read feed tags carefully. Cost should not be the sole consideration.

Vitamins in a mineral-vitamin supplement will lose their potency over time. For this reason it is important to keep mineral-vitamin supplements fresh, cool, dry and out of direct sunlight. Only as much supplement as can be consumed in a 90-day period should be purchased or mixed at one time. You may want to check with your feed manufacturer to verify the date on which the supplement was made.

Vitamins A and E are high in fresh forages and are relatively expensive ingredients in the mix. Excluding these vitamins from a supplement fed to cattle grazing fresh forages may help reduce the cost of supplementation. However, these vitamins should be supplemented to cattle receiving harvested forages.

Consumption

Managers should record the amount and date of mineral feeding so consumption can be monitored.

Underconsumption

Underconsumption may negate the benefits of mineral supplementation. Some producers have indicated that consumption of these mixes falls to extremely low levels during certain times of the year. This is often a result of the mineral mix getting wet, caking and becoming hard. (See mineral feeder considerations below.)

Another factor that may contribute to a low consumption rate is magnesium oxide, which is unpalatable. This can be overridden somewhat by a sweetening agent. Consumption also rises and falls during periods of the production cycle. Generally, consumption is higher in spring and early summer with succulent forage and during peak lactation. Consumption declines later in the pasture season and after calves are weaned. In some areas, drinking salty or brackish water will reduce mineral consumption. If self-fed mineral mixes are to be used, this should be the only source of salt available. If consumption becomes a problem, it may be necessary to increase the amount of sweetening or flavoring agents.

Mineral feeder considerations

Feeder design and location are important to maintain consistent mineral-vitamin mix consumption. Place feeders in areas that cattle frequent, such as near water, loafing areas, back rubbers, etc. It is important to keep the mix in a well constructed self-feeder that limits exposure to precipitation or in a sheltered trough. Watch for caking, mold, manure and other contamination.

Cattle licking and salivating on the mix may also cause caking. Therefore, keep the mix fresh and do not feed too much at one time, but keep mineral in the feeder at all times to encourage steady consumption.

Table 1. Beef cow mineral-vitamin nutrient requirements and an example mineral-vitamin supplement mix.

Ingredient	Concentration in mixed hay (DM)[a]	Estimated daily nutrient intake from 25 lb mixed hay (DM)	Dietary requirement (% or ppm)[b]	Calculated daily requirement assuming 25 lb mixed hay intake (DM)	Desired average intake as % of requirement[c]	Mineral-vitamin source	Mineral-vitamin nutrient concentration in source	Amount of source needed in daily supplement intake	Concentration of source in supplement mix, %	Final supplement, lb/ton
Sodium	0.027 %	3 g	0.10 %	11 g	100 %	White salt	39.0 % Na	21.23 g	27.239 %	545
Chlorine	0.55 %	62 g	n/a	n/a	100 %	_[d]	_[d]	_[d]	_[d]	
Calcium	0.55 %	62 g	0.37 %	42 g	110 %	_[d]	_[d]	_[d]	_[d]	
Phosphorus	0.22 %	25 g	0.25 %	28 g	110 %	Dicalcium phosphate	21.0 % P	29.70 g	38.113 %	762
Potassium	1.84 %	209 g	0.70 %	79 g	100 %	_[d]	_[d]	_[d]	_[d]	
Magnesium	0.21 %	24 g	0.20 %	23 g	140 %	Magnesium oxide	57.0 % Mg	13.93 g	17.871 %	357
Sulfur	0.15 %	17 g	0.15 %	17 g	100 %	_[d]	_[d]	_[d]	_[d]	
Manganese	34 ppm	386 mg	40 ppm	454 mg	150 %	Manganese sulfate	32.0 % Mn	921.38 mg	1.182 %	23.65
Molybdenum	1.4 ppm	16 mg	n/a	n/a	n/a	_[d]	_[d]	_[d]	_[d]	
Zinc	23 ppm	261 mg	30 ppm	340 mg	150 %	Zinc sulfate	35.5 % Zn	702.76 mg	0.902 %	18.04
Iron	131 ppm	1486 mg	50 ppm	567 mg	100 %	_[d]	_[d]	_[d]	_[d]	
Copper	8 ppm	91 mg	10 ppm	113 mg	150 %	Copper sulfate	25.2 % Cu	315.00 mg	0.404 %	8.08
Selenium	0.151 ppm	2 mg	0.10 ppm	1 mg	400 %	Sodium selenite	1.6 % Se	176.48 mg	0.226 %	4.53
Iodine	n/a	n/a	0.50 ppm	6 mg	100 %	EDDI[e]	79.5 % I	7.13 mg	0.009 %	0.18
Cobalt	0.2 ppm	2 mg	0.10 ppm	1 mg	400 %	Cobalt sulfate	33.0 % Co	9.45 mg	0.012 %	0.24
Vitamin A	0 IU[f]	0 IU[f]	1,770 IU/lb	44,250 IU	100 %	Vitamin A 650	650,000 IU/g	0.07 g	0.087 %	1.75
Vitamin D	0 IU[f]	0 IU[f]	125 IU/lb	3,125 IU	_[g]	—	—	—	—	
Vitamin E	0 IU[f]	0 IU[f]	6 IU/lb	150 IU	100 %	Vitamin E	1,000 IU/g	0.15 g	0.192 %	3.85
Soy oil, mineral oil or equivalent	—	—	—	—	—	Oil	—	.97 g	1.250 %	30
Molasses or equivalent sweetener	—	—	—	—	—	Sweetener	—	5.85 g	7.507 %	150
Inert carrier	—	—	—	—	—	Grain byproducts, etc.	—	3.90 g	5.005 %	95
							Total	**78 g[h]**	**100.000%**	**2000 lb**

[a] Na, Cl, Ca, P, K, Mg, S, Mn, Mo, Zn, Fe and Cu are lowest average values for legume hay, mixed (mostly legume), mixed (mostly grass) and grass hay from DHIA (1995). Se and Co values are lowest average values for Midwest alfalfa, brome and grass (Corah and Dargatz, 1996).

[b] From NRC 1996, early lactation cow.

[c] Values greater than 100% attempt to compensate for variation in feedstuff nutrient content as well as individual animal supplement intake.

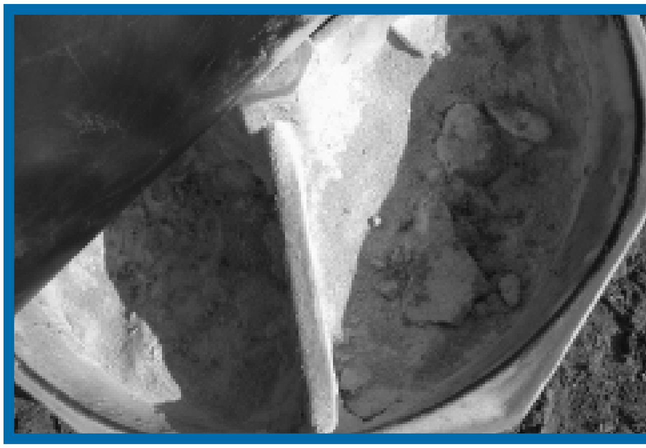
[d] No source or amounts are given because estimated daily nutrient intake from 25 lb mixed hay meets or exceeds the desired average intake.

[e] Ethylenediamine dihydroiodide.

[f] Assuming no vitamin activity in forage.

[g] Cattle exposed to sunlight (ultraviolet rays) should not require vitamin D supplementation. Beef cows in strict indoor confinement may require dietary vitamin D supplementation.

[h] Average daily supplement consumption formulated to be 78 g (0.17 lb).



Example of caking of mineral-vitamin mix.

Overconsumption

Mineral and vitamin supplementation should be carefully balanced. Provision of a particular mineral, because of its attributes, in gross excess of requirements will likely be detrimental to absorption of other minerals. This, in turn, may cause a deficiency of other minerals. In addition, cattle may overconsume a mineral mix if it is appetizing and eat much more than they require. Maximum tolerable concentrations of minerals for cattle are given in Table 3.

Overconsumption will unduly increase supplementation costs. It should also be avoided to prevent possible environmental problems associated with runoff from animal waste or manure application to soil. Overconsumption for a few weeks may be expected if cattle have been mineral deficient for a period of time. If overconsumption continues for several weeks, mineral-vitamin supplement intake can be limited by incremental addition of white salt.

Inorganic vs. organic sources

Organic elemental complexes (organics or chelates) may in some cases have higher rates of absorption than ionic elemental forms (inorganic). The potential benefit of organic mineral sources needs to justify their additional cost.

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Table 2. Some mineral sources and their relative bioavailability for cattle.

Mineral	Source	Relative Availability
Cobalt	Carbonate	?
	Sulfate	?
Copper	Basic chloride	High
	Sulfate	High
	Proteinate, lysine	High
	Carbonate	Intermediate
	Oxide	Low[a]
Iodine	Calcium iodate	High
	Ethylenediamine dihydroiodide (EDDI)	High
	Potassium iodide	Unstable
	Sodium iodide	Unstable
Magnesium	Oxide	High
	Sulfate	High
	Dolomitic limestone	Low
	Magnesite	Low
Manganese	Amino acid chelate	High
	Sulfate	High
	Methionine	High
	Polysaccaride complex	High
	Proteinate	High
	Oxide	Intermediate
Selenium	Sodium selenate	High
	Sodium selenite	High
Zinc	Sulfate	High
	Methionine	High
	Oxide	High
	Proteinate	High

[a]Although feed-grade copper oxide is largely unavailable, ruminal slow-release copper oxide needles have been used as a copper source.

Table 3. Maximum tolerable concentrations of minerals for cattle.[a]

Nutrient	Maximum tolerable concentration in diet DM
Calcium	20%
Chlorine	n/a
Chromium	1,000 ppm
Cobalt	10 ppm
Copper	100 ppm
Iodine	50 ppm
Iron	1,000 ppm
Magnesium	0.40 %
Manganese	1,000 ppm
Molybdenum	5 ppm
Nickel	50 ppm
Phosphorus	10%
Potassium	3 %
Selenium	2 ppm
Sodium	n/a
Sulfur	0.40 %
Zinc	500 ppm

[a]From NRC 1996.

Definitions

Anion — a negatively charged atom or group of atoms

Cation — a positively charged atom or group of atoms

DM = dry matter

g = gram (1,000 g = 1 kg; 454 g = 1 lb)

IU = international unit (based on a specified level of bioactivity)

kg = kilogram (1,000 kg = 1 metric ton)

mg = milligram (1,000 mg = 1 g)

ppm = parts per million (1 ppm = 1 mg/kg or 0.002 lb/ton)

References

Berger, L. L. 1996. Variation in the trace mineral content of feedstuffs. Prof. Anim. Sci. 12:1-5.

Corah, L.R., and D. Dargatz. 1996. Forage analyses from cow/calf herds in 18 states. Beef cow/calf health and productivity audit. Fort Collins, Colo.: USDA:APHIS:VS Centers for Epidemiology and Animal Health.

DHIA. 1995. Northeast DHIA Forage Lab Tables of Feed Composition. Ithaca, New York: Northeast DHIA.

Faustman, C., W. K. M. Chan, D. M. Schaefer and A. Havens. 1998. Beef color update: The role for vitamin E. J. Anim. Sci. 76:1019-1026.

National Research Council. 1996. Nutrient requirements of beef cattle (7th rev. ed.). Washington, D.C.: National Academy Press.

Petersen, M. 1999. Considerations in trace mineral supplementation. Beef Cattle Handbook BCH-5455. Madison, Wis.: University of Wisconsin Extension.

Ritchie, H., and C. Gibson. 1992. Mineral mixes for Michigan beef cow herds. Animal Science Staff Paper 253. East Lansing, Mich.: Michigan State University.

Wikse, S.E., 1992. Proceedings of the 1992 TAMU Beef Cattle Shortcourse. College Station, Texas: Texas A&M University.

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